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Ferrari took its first win on home soil with the 499P at Imola, the second round of the FIA World Endurance Championship in April. BMW and Alpine rounded out the podium

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Presidential aspirations

An election is a-coming, and the mud has already started to fly

It's silly season in politics once again, which signals that there is an election due. No, not the US Presidential, that's following its own hazy, wavy path. This is the presidency of the FIA, the sport's governing body, and it has already started to get a little fruity.

Deputy president, Robert Reid, has resigned; the head of Motorsport UK, David Richards, has publicly called out the FIA on transparency; the Formula 1 and World Rally Championship drivers are up in arms due to what they see as over regulation. In the latter case, they protested a driver's fine for swearing by answering stage-end interview questions in their mother tongue or not at all.

Former WRC co-driver, Reid, arrived alongside the president, Mohammed Ben Sulayem, and it was a relief to many to be out of the auspices of the previous administration that, I believe, threatened the existence of professional motor racing. Reid's tenure lasted until April 2025, and his resignation came shortly after Richards made his criticisims of the governing body public, which came after the FIA asked him to sign a confidentiality agreement, on top of that to which he was already bound.

Three pillars

Richards complained that he had campaigned alongside Ben Sulayem on three pillars: to be a hands-off president, to appoint a CEO to run the FIA, and full transparency of actions, saying, 'there has been a distinct failure to meet these promises.'

The FIA dismissed his concerns, and asked that Motorsport UK publish its letter too, in which it pointed to the successes of the FIA, and the damage inflicted on its reputation by leaks.

Richards responded: 'What is disappointing in this letter from Alberto [Villarreal, FIA general manager] is the disregard for the very real concerns that have been expressed, not just by myself, but a growing number of people, that the governance and constitutional organisation of the FIA is becoming ever more opaque and concentrating power in the hands of the president alone.'

We could speculate over whether those that once walked the corridors of power are throwing their support behind another candidate, such as Susie Wolff, whose name has been linked to the role. We could also hypothesise on who is right, or who is at fault, but I'm not sure that would help anyone. Perhaps best leave that topic for over a pint or two in the pub.

What is clear is that there has been a major overhaul at the FIA, with personnel leaving in their droves. Amongst them race director, Niels Wittich, who stepped down in November last year, only to surface in the GT World Challenge this season. He followed Formula 2 race director, Janette Tan, and race steward, Tim Mayer, out of the door. Then there's the director of communications, Luke Skipper, general secretary of mobility, Jacob Bangsgaard, and road sport director, Andrew Wheatley. To that list we can add the FIA's director general, Natalie Robyn, F1 sporting director, Steve Nielsen, and single seat director, Tim Goss.

FIA President Mohammed Ben Sulayem is under increasing pressure from those who used to walk the palace of power, but to what end?

Turnover of staff is not a problem. Some would say that there needed to be new wave of personnel appointed, but so many leaving in a short space of time is a problem. They all left for different reasons, some of their own volition, others not but their roles still needed to be filled.

We have long campaigned for the FIA to reduce its reach. The FIA was set up as a sporting club, but its main job is to improve road safety. Its role in motor racing extends to safety of circuits, cars, marshals and spectators. It also oversees, by committee, the regulations of each individual championship and sets the engineering path for future technologies.

Over reaching

However, it has delved into areas that simply don't need a rummage. Banning team members from even talking about race-deciding events, such as balance of performance for example, is over reaching, and certinaly not conducive to transparency.

However, according to Villarreal's open letter to Richards, available online, the FIA has succeeded in getting the club back onto its feet financially. It has succeeded in its core message, which is to help encourage younger participants into the sport by providing accessible formulae. The Cross Car, featured in this edition, is one part of delivering on that promise, along with the Motorsport in a Box initiative, and the Global Karting Plan.

Safety, accessibility and financial stability were core pillars on which Ben Sulayem built his candidacy, and he has delivered.

However, whenever there is an election, or a major contract to be signed, the political stories accelerate, and it's easy to get lost in the noise. The very basic fact is that this is a democratic election. Sure, you need the wealth to travel around the world, securing the support of the various ASNs to vote for you, but that's no different to a national political election. It's just global, and takes more money than most have.

The first thing to do if you are going to challenge is attack the president, make the office weaker, and then confirm your candidacy. The first rocks have been thrown. Let's now wait and see why the first was thrown, and who will throw the last.

What is clear is that there has been a major overhaul at the FIA, with personnel leaving in their droves

Heart of Haas

Despite a rocky start to the 2025 season, the American-owned F1 team has put some early points on the board, but can it match its best ever result?

By DANIEL LLOYD

Five races into its best season to date in Formula 1, the Haas team had scored 19 points. Five races into the current campaign and the American-owned squad had eclipsed that figure by one.

Of course, it is too early to dare predict whether Haas will match its personal best fifth-place finish in the World Constructors' Championship from 2018, but it is currently dicing with a resurgent Williams for that position, and the numbers look inviting. What is certain is that the Haas VF-25 has sprung from the gates quicker than its VF-24 predecessor did 12 months ago, when the team finished seventh.

If Haas does remain a top five candidate as the 2025 season unfolds, it would be remarkable considering the disastrous opening race the team had in Australia, where fierce oscillations of the floor in a particular sequence of corners made it by far the slowest car. Overcoming that issue quickly became one of the team's priorities in the opening third of the campaign.

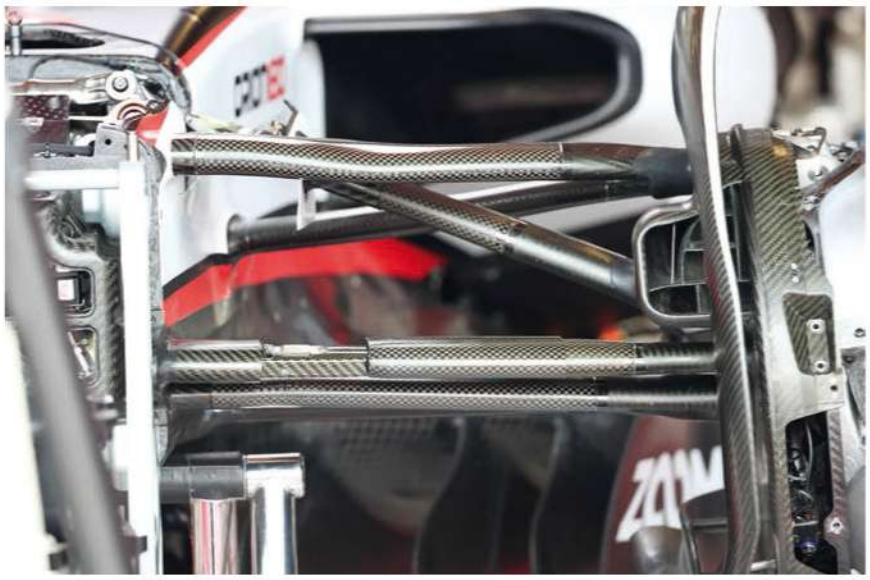
Engineering-led

The VF-25 is the first Haas F1 car to be fully developed under the leadership of Ayao Komatsu, who replaced Guenther Steiner as team principal just before the 2024 season started. When that change happened, the

The Haas VF-25 is an evolution of last year's car and is continuing its predecessor's points scoring capability

'The chassis is… a little bit longer. The rear part of it is basically carried over, but the cooling system changed in position to allow more aero freedom'

Andrea De Zordo, technical director at Haas F1



Rather than follow the route its supplier, Ferrari, has taken, Haas chose to retain its pushrod front suspension from '24. The pushrod is the diagonal arm sloping down from the top of the chassis that operates the damper via a rocker

This year's front wing end plate was revised to better control front wheel wake and its effect on the parts downstream

big question was whether Haas would fare better with a management structure led by its former director of engineering. The engineering-led operation plugged away, making the car kinder on its rear tyres and suitable for a wider range of tracks.

The VF-25 is a continuation of that approach. Recently, Komatsu has sought to bolster the team with changes to key trackside staff, hiring two new race engineers promoted from within, plus investment in the design office at Maranello and a new partnership with Toyota Gazoo Racing.

'We had some expectations, and the data is confirming it's as expected,' says Haas technical director, Andrea De Zordo. 'We haven't done everything spot on in the preparation of the car, but I don't think it's dramatic things, it's just an adjustment. Race by race, we are setting targets and improving step by step. I think we have improved last year's car in general characteristics.'

As was the case last year, Haas sought to increase downforce that works when the car needs it most. 'This was the main factor in trying to find performance,' adds De Zordo. 'In parallel, we know the 2024 car had some weak areas that were nothing secret. Listening to the comments of competitors, we have more or less the same weakness [as them]. With this generation of car, it is difficult to be fast in both high and low speed, because the car characteristics change a lot. I think the focus of all competitors in the last couple of years has been trying to find a way to make the car work nicely in both conditions. You can do that through aero development, but also by mechanical characteristics.'

Winter changes

The most visible technical item on the VF-25 when it was unveiled at a grey Silverstone in mid-February was something that had not been changed. Since its 2016 debut, the team has purchased as many parts as it can from its power unit supplier, Ferrari. The suite of components includes the engine, gearbox and suspension. For 2025, Ferrari opted to change from pushrod to pull-rod front suspension, saying its engineers had extracted all they could from the former.

Haas, however, elected not to follow suit, choosing to retain the pushrod suspension arrangement of the previous year.

Timing was undoubtedly a factor in the decision. By continuing with the same layout, Haas had more time to work on the suspension's dive, squat and airflow characteristics than if it had purchased Ferrari's 2025 package. The team therefore entered the season with updated front suspension fairings for aerodynamic reasons, in conjunction with a new load pattern on the front wing, concentrating it on sections where wake from a car in front is less harmful.

The rear suspension fairings were also re-designed to condition the airflow coming off a new ground-effect floor. In this instance, Haas followed Ferrari by sticking with a pull-rod layout. Further upstream, Haas slimmed the sidepods on the VF-25 to increase the space underneath, maximising the amount of air passing through, and brought the P-shaped sidepod inlets forward to improve cooling performance in low-drag scenarios. These alterations to the sidepod shape led to a major re-packaging of the cooling system within.

'It is a big chapter of car development,' suggests De Zordo. 'The cooling system is very heavy and big in dimensions, and you have to accommodate that with the best aero shape possible. There [was] a lot of work on the cooling system itself. We tried to make it as efficient as possible, in a way that you reduce both inertia and weight. You need it in the car but, at the same time, it's a big constraint in aero. There has also been a lot of work on the thermal layout to find the best packaging that doesn't stop the aerodynamics.'

Additionally, Haas lengthened the chassis of the VF-25, somewhere between 20-30mm according to the technical director, although this modification was made to accommodate updates to the front suspension, not aero.

While many teams have narrowed their sidepod inlets this season, Haas has maintained a more pronounced opening, as a development of last year's design. The sidepods themselves are slimmer than those of the VF-24

A deeper sidepod undercut drew Haas into the challenge of re-packaging the VF-25's cooling system within

'The chassis is not the same,' adds De Zordo. 'It's very similar, just a little bit longer. The rear part of it is basically carried over, but the cooling system changed in position to allow more aero freedom [with] a bigger undercut and smaller sidepods. We also made some adjustments to the front suspension to try to change some mechanical characteristics.'

Breaking cover

Shakedowns of new F1 cars tend to be rather drab affairs from the outside, beyond the initial buzz of a new machine taking its first steps. Usually, the driver can be expected to perform a handful of installation laps at greatly reduced speed, and little more. However, sometimes things go wrong, which is when it starts to get more exciting. Haas encountered this with the VF-25, which was photographed on track by observers with part of its engine cover missing. Rather than being an isolated teething issue, the same thing then occurred at pre-season testing in Bahrain over a week later.

'It made the start of the season quite difficult because we had to react quickly and it took resources and time during the test,' reflects De Zordo. 'In terms of what happened, I think we maybe pushed a little bit too much. At the same time, a couple of things were not done very well, and they worked together in a bad way, resulting in the problem [of detaching bodywork].'

Haas could at least deal with the issue before competitive running started but, with so little testing time available, it still has to be considered a hit. In bolstering the panel, it added a 'little bit of weight', although De Zordo indicates that the engineering group had been trying to give the VF-25 a wider ballast margin than its predecessor.

In F1, cars may be built lighter than the minimum weight of 800kg, provided they carry ballast to make up the difference.

A problem with detaching bodywork in pre-season testing caused Haas to concede some of the weight margin it had built into its 2025 challenger

Having a ballast margin gives engineers more to play with in terms of weight balance. The increase in weight Haas accepted to seal the bodywork better ate into its margin.

'At the beginning of 2024, when we weighed the car for the first time, it was a little bit heavier than expected,' admits De Zordo. 'So we had to work quite a lot during the 2024 season to make it fine. For this reason, we tried to keep it more under control for 2025. Maybe this was one of the reasons why we were quite aggressive with the bodywork.'

Off the pace

Haas posted the slowest lap times at testing, but no alarm bells rang because it was prioritising long runs. However, when the best VF-25 was 1.8 seconds adrift in first practice for the Australian Grand Prix at Melbourne's Albert Park, there was no such precedent to rely on. The team almost instantly discovered an unwanted characteristic of the VF-25, whereby it would bounce through certain high-speed corners. The oscillations were manifesting at Turns 9 and 10, an extremely fast left-right taken at roughly 235km/h. They were also felt at Turn 12, but without the drivers needing to ease off. Stuck at the furthest flyaway round from home, the only solution was for drivers, Esteban Ocon and Oliver Bearman, to take those corners slower, the instability robbing them of the confidence to post competitive lap times.

On top of that, an accident for Bearman exiting Turn 10 during FP1 forced his car out of FP2, while a spin into the gravel during FP3 meant Haas was limited in the amount of data it gathered. Engineers were left scratching their heads, observing that the oscillations persisted despite mechanical set-up tweaks.

'It is not something we can prove because you cannot replicate some of these conditions in the wind tunnel,' says De Zordo.

'It is physically impossible because you would scratch the ground and break the tunnel. We have some theories, but it's not very easy to explain. It's something we are trying to replicate in CFD, because it's the only way you can simulate it. We haven't done it properly yet, because it's something unexpected. We have some metrics to check the bouncing in a straight line, but we didn't expect this problem in the corners, so we didn't have a metric to check it.'

De Zordo goes as far as saying that the car's performance in Australia was the worst he had seen since joining Haas at the start of 2021. An immediate response was clearly required, although nothing could be done in time for the Chinese Grand Prix the following weekend. Fortunately for Haas, the smoother surface at Shanghai International Circuit kept the unchanged VF-25 in a more stable state through the high-speed turns. Ocon rose from 11th on the grid to seventh, taking advantage of his strategy of starting on medium tyres and spending the rest of the race on hards. After both Ferrari SF-25s were disqualified for separate infractions, the Frenchman was boosted to fifth, giving Haas its best result since the 2022 season opener.

Bearman finished in eighth, but that 14-point haul didn't hide the fact that Haas was worried the floor issues would return if updates weren't rolled out.

Ambitious target

Round three at Suzuka in Japan, three weeks after Australia, was set as an achievable, if ambitious, target. The aerodynamics team, led by Davide Paganelli, convinced De Zordo with an idea of how to approach the problem. In impressively little time, they adjusted the volume and proximity to the ground of the floor's central section and sent the newly modelled part halfway around the world.

De Zordo goes as far as saying that the car's performance in Australia was the worst he had seen since joining Haas at the start of 2021

'We had a meeting just after Australia; it [took around] 30 minutes,' says De Zordo. 'We released the modification for production, because there was no [other] way to have the floor ready in time for Japan. [Due to] characteristics of the circuit, it was very risky to have the same problem. [Australia] was a tough race, but I also think the reaction we had was quite a good feeling for us, because we had to react properly and all together.'

Haas tested its updated floor in the Ferrari wind tunnel, but only after it had signed off production of the part that would be raced in Japan. There was relief when the retrospective wind tunnel run produced no evidence that the update had worsened the oscillations, instilling a shred of confidence that the parts in transit to Suzuka would work in practice.

The team also worked on the car's mechanical set-up to keep the ride height as stable as possible for consistent underfloor airflow. Haas did back-to-back comparisons with and without the updated floor before racing it on both. Bearman went on to finish 10th, collecting a single point. This delighted Komatsu, who said afterwards the team's data showed it had reduced the oscillations.

Moving forward, the team intends to further develop the floor to expand on the plaster solution it produced for Japan. At Suzuka, just the central section of the floor was altered, rather than the diffuser, the fences at the front of the floor and the edge details that poke out from each side. Typically, a team would make changes in all areas when updating its main ground-effect device.

Platform stability

'We are planning some other developments, and we are taking them into consideration with the experience of [developing] this new floor,' confirms De Zordo. 'We were confident at the beginning of the season, but then we discovered this problem. What we are doing for the next floor is just trying to find performance, but also going in the direction of mitigating this possible problem.'

The Italian adds that there is a caveat in this generation of F1 cars where a tipping point emerges, rendering further intended remedies unhelpful. Identifying where this threshold lies with regards to the VF-25's floor is an ongoing task.

'For sure, we will never fix the problem,' states De Zordo. 'Because as soon as it gets better, we will push more, and it is very likely something else will happen. In Bahrain, Ayao asked me when we will have completely fixed the bouncing. I said we will never do that, because when we fix something, we push more and find something else.'

Further developments will not just be about adding downforce and ensuring platform stability. Haas recognises it has a weakness in low-drag scenarios, Komatsu saying after the Japanese Grand Prix that it has a DRS deficit to its rivals.

Profiling the floor's underside too close to its bouncing limit can easily push the car out of a stable operating window, as Haas found out when the VF-25 turned laps in Melbourne

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In Saudi Arabia, where the team brought two low-drag rear wings from its 2024 car, both VF-25 drivers were 6km/h off the fastest speed trap figure in qualifying, suggesting there is work to do in this area.

Design upgrades

The introduction of a quick fix to the floor was noteworthy for a team that only put one major update on its car during the 2023 season. The frequency of new parts increased last year, as the team invested in better tools for its staff at the Maranello design office to use. According to De Zordo, about 130 people work in that facility, which supports the operations and race engineering centre in Banbury, UK and the corporate headquarters in Kannapolis, North Carolina.

'We made a few changes in the last year,' he says. 'The design [office], in general, is growing a lot. It is still something that is evolving over time, and there is still a lot of things to do. We have tried to integrate as much as possible the departments, to speed up processes. We are involving the production department very soon, to make sure it's integrated and sped up. I think the aero department has made a lot of improvements, in terms of analysis tools and making faster calculations, but this also relates to the improved technology. There are always faster computers and it's nice to use that.

'In terms of what we can still improve, there are quite a lot of new trends in the [current] technology that we are still not on top of. There is still a lot to take from that, making all prediction tools better and faster.'

Toyota tie-up

In October 2024, Haas and Toyota announced the start of their partnership, which from the team's side was aimed at bolstering its resources. It was a major scoop for Haas, which for many years has been seen as one of the more dependent teams on its power unit provider and external suppliers, such as Dallara, which builds the chassis.

The Toyota deal, combined with the decision not to adopt Ferrari's latest front suspension, pointed towards Haas exerting greater autonomy. Aside from Toyota logos appearing on the VF-25 and team apparel, the Japanese automotive giant is getting more involved with the operational side. Its engineers have been deployed during tests with previous cars [TPC] and one of its 24 Hours of Le Mans winners, Ryo Hirakawa, has become Haas reserve driver. Toyota is also helping Haas develop its own driver-in-the-loop simulator, which is expected to be operational by the end of this year.

Teams use simulators not only to train drivers for upcoming races, but to try set-up options during race weekends that are not feasible in the limited on-track practice time.

Toyota is helping Haas to develop its own driver-in-the-loop simulator, which is expected to be operational by the end of this year

'It is something that will take some time to build up completely,' acknowledges De Zordo. 'It started well, with the TPC programme. This is important for us, having the opportunity to train new people [for] trackside activity. It will be important for the programme with the simulator that we are trying to develop now as currently we don't have one. There is a lot of potential, and many things to do together.'

The Toyota partnership is set to develop further this year and continue into 2026, when the new regulatory era begins. Haas is currently undergoing a programme of switching its resources from the VF-25 to next year's car. Wind tunnel and CFD testing for the 2026 machinery became possible in January, but Haas has not put all its eggs in that basket yet. Instead, the team opted to start with CFD evaluation of the 2026 aerodynamic concept ahead of any physical research, meaning the VF-25 initially had more time in the tunnel.

'Now, the main focus is still on 2025, but day by day we are switching,' confirms De Zordo. 'It's quite difficult because, when you see the fight on the track for 2025, you would like to put all the resources on that to keep fighting. But it's important to stay cool and follow the plan. I think, probably close to the summer, the switch to 2026 will be complete'

It will be a challenge for Haas to replicate its personal best result in the Constructors' Championship. How it further develops the VF-25 out of the early floor issue will be key to the trajectory of its campaign from here. Then again, the team has progressed enough in recent months to be considered a solid midfield runner. It is in a much better place than halfway into the current rules cycle, at the end of 2023, when it was at the foot of the table with a car that chewed through its tyres. The turnaround is giving Haas something on which to build, increasing its chances of a smooth transition into 2026.

Technical chief

Andrea De Zordo is not one of the best-known technical leaders currently working in F1, certainly compared to the likes of James Allison at Mercedes and Pierre Waché at Red Bull. However, the Italian has been in the game for many years. Hailing from Faenza, De Zordo first gained employment with his local team, Minardi, as a stress engineer in 2001. After three seasons, he joined McLaren as a senior design engineer. That five-year stint included working on the MP4-23 in which Lewis Hamilton claimed his first of seven drivers' titles.

De Zordo then returned to Italy's Motor Valley with Ferrari in 2009, rising to the rank of deputy chief designer, which he held for six years until being assigned to Haas in 2021. When Guenther Steiner's director of engineering, Ayao Komatsu, became Haas team principal last year, he installed De Zordo as technical director, replacing a Mercedes-bound Simone Resta.

De Zordo became technical director last year and, after feeling intense pressure in the early days, has now settled into the role, which he says requires more liaison with other departments

De Zordo doesn't see much time in the limelight because Komatsu, an engineer by trade, usually satisfies the technical questions of the media during race weekends. However, De Zordo carries a great deal of responsibility when it comes to ensuring the different technical departments at Haas are working coherently.

'Twelve months is a short time, but it was a long journey,' he says, reflecting on his first year in the role. 'Initially, when it happened, this change was not prepared in advance, and everything happened very fast. On the morning of the day they asked me to be technical director, I hadn't thought of it when I woke up. Everything changed, and initially it was very difficult.'

De Zordo admits he 'felt the pressure' of stepping into a more senior technical position, but has grown into the role. 'Step by step, I took confidence with it, and it [became] more relaxed and easier to deal with,' he says. 'Something that helps me a lot is that I work with really good, experienced people. I had to detach from the role of chief designer, keeping an eye on design but starting to look more widely into all technical aspects of the business. It was a mental switch that I had to do.

'Also, I have been getting more involved in the organisation side of things. Looking back, the group of people that works with me has grown a lot, too. We [have become] more used to working together and are stronger than we were before. We tried to promote a good working environment, and I think that makes it easier to build a good car.'

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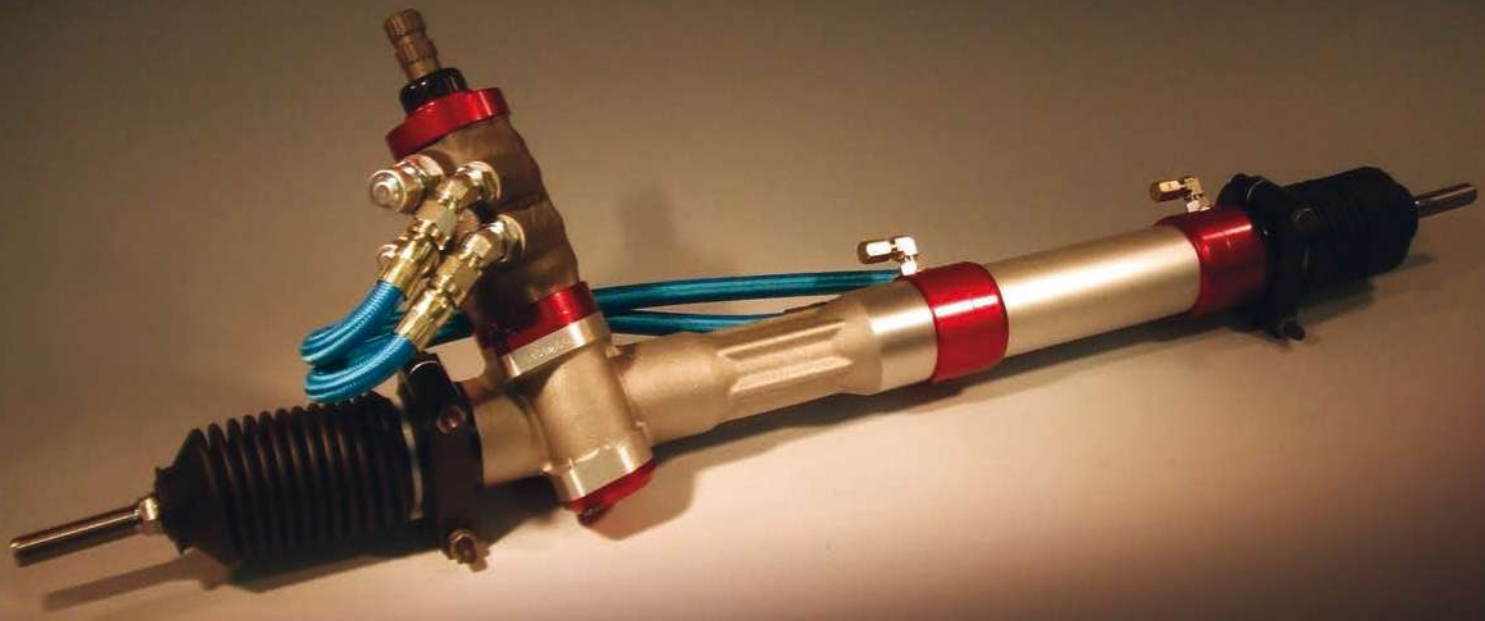

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Having caught the F1 bug watching ground-effect cars in the 1970s, Tombazis' time in the sport came full circle when he helped put together the current technical regulations that arrived in 2022

Living for F1

The FIA's single seater director had one goal as a child: Formula 1. After winning several world titles as an engineer, he is now trying to improve the sport

By CHRISTIAN MENATH

Nikolas Tombazis was born into a cradle of creating and achieving extraordinary things. His grandfather climbed mountains in the Himalayas in the 1920s and his father, Alexandros Tombazis, was one of the most famous architects in Greece. It seemed only logical, then, that young Nikolas might climb to the top of his chosen profession, too. The field he pursued was design, specifically Formula 1 cars. The FIA's current single seater director spent many years of his life helping develop some of the fastest and most successful machines to have hit the track.

Tombazis contributed to winning 15 drivers' and constructors' titles at Benetton and Ferrari, rising through the ranks from junior aerodynamicist to chief aerodynamicist and then to chief designer.

'My father let me do what I wanted,' recalls the Greek. 'I was a bit too cocky as a kid and didn't want to just do what my father did.' Growing up in Athens – a place better known for its rallying heritage than any association with Formula 1 – he set his sights on motorsport as a career path early on. When German architect friends of his parents invited him, aged 11, to the 1979 German Grand Prix at Hockenheim, the F1 spark was immediately ignited.

'The first race was pretty special,' he remembers. 'I had my favourite drivers, my favourite teams and all of that. It was the time when the ground-effect cars were coming about and there were all the sketches of Giorgio Piola, with red arrows and green arrows [showing the cars' different features]. I found all that aerodynamic stuff fascinating.

'As a kid, I used to design my own cars. My friend used to do that as well and we would compare them. I was definitely what you would consider a hardcore fan.

'I was really decent in maths and physics at school. I also liked cars, and I liked designing things, so all of these things pointed to that career primarily.'

'I was really decent in maths and physics at school. I also liked cars, and I liked designing things, so all of these things pointed to that career [in F1] primarily'

Nikolas Tombazis – FIA single seater director

Further education

At the age of 18, Tombazis left Greece to study in the UK. 'I chose Cambridge [University] because it had a general engineering course. In that respect, I felt you learnt a bit of mechanics, a bit of aerodynamics, a bit of electronics and a bit of materials. You had a fairly wide range. I thought that would be useful for my subsequent career, and that it would give me a reasonable understanding of areas that were not my direct expertise.'

Tombazis wanted to go to America afterwards to do a PhD, but ended up staying in the UK to pursue his love for motorsport. 'I was extremely passionate about Formula 1, but in those days jobs in the championship were rarer; the teams were much smaller. I knew that Imperial College London had a wind tunnel that some teams occasionally used back then, so I felt that would put me in a slightly better place. Also, my PhD in America would have taken about five years. At Imperial, I could do it in three and was closer to Formula 1, so I thought I'd go there.'

In 1992, Tombazis finished his doctorate in aerospace, aeronautical and astronautical engineering, having already secured a job offer from the Benetton Formula 1 team. 'I remember having to rush to finish my PhD in order to start,' he recalls.

The young engineer had responded to an advert in *Autosport* magazine. 'That's where it all used to happen in those days. I felt I had a rather outside chance of getting the job because it said previous experience was preferable, but fortunately, I think was in the right place at the right time.'

Aerodynamic path

In 1992, Tombazis started at Benetton as a junior aerodynamicist. 'The aerodynamics department back then was about eight people,' he says. 'There was my boss, who was Willem Toet. I was junior aerodynamicist, then there were two CAD designers and four model makers. That was it.'

In today's F1 teams, the aerodynamics department alone consists of around 150 employees but, at the beginning of the 1990s, each person in the much smaller teams had a correspondingly large area of responsibility.

The 1992 season was Tombazis' first in Formula 1, having secured a junior aerodynamicist position with Benetton while working on his PhD

One of Tombazis' first tasks was to introduce computational fluid dynamics to the team. 'CFD was in its infancy back then,' he remembers. 'I had to find which software to use and set it up. That didn't go very far as it was way too immature back then, so it really wasn't giving anything useful. I learnt a lot, but I don't think my CFD contributed to the team that much,' admits the 57-year-old.

He obviously did something right though as, two years later, Tombazis was promoted to head of aerodynamics. 'It was a combination of capability and fortune,' he says. 'I wouldn't like to put it down to one or the other. Back then it was a lot more difficult to get into Formula 1 than it is now but, once you were in, you would go up a lot more quickly if you were half decent. My boss went to Ferrari and that left an empty position. I think I had done a not too bad job up until then, and so I was given the opportunity.'

Benetton's heyday

Benetton experienced its heyday in the mid-1990s, winning the World Drivers' Championship in 1994 and doubling up with the Constructors' Championship a year later. This was achieved through a combination of the leadership of Flavio Briatore, the brilliance of Michael Schumacher behind the wheel and a dream team in the engineering offices.

'CFD was in its infancy back then [in 1992]… I learnt a lot, but I don't think my CFD contributed to the team that much'

'Back then my boss was Rory Byrne,' says Tombazis. 'I had huge respect for Rory; I still have. The nice thing I had with him was that he was not an aerodynamics expert. None of the guys back then – not even the head of aerodynamics, my initial boss – were experts. They hadn't had formal training, they had just grown into it, sort of empirically. Rory was the same, so he would never come to me and say, "I think you should make your wing this way, or the diffuser that way." It was more discussion about the car and about the overall interaction of aerodynamics with the rest of the car that was interesting.'

Tombazis learnt early on that success in F1 required more than just good engineering skills. 'The other thing with Rory was that there was no ego there at all. We would frequently have different opinions on something, but we'd discuss it, and we'd agree things. It was always objective analysis and then if, out of facts, it came out that his idea was not so good and mine was better, he would be equally happy. He didn't have any desire to prove he's smarter, or anything like that. In Formula 1, there are a lot of people who have that desire. So I appreciated more Rory's creative input, his energy and his overall understanding of the car.'

Ross Brawn was also part of that dream team, although Tombazis admits he only started to properly understand his contribution in subsequent years. 'I did not yet appreciate Ross so much because I was quite young, and I didn't realise how important it is to organise a team. Ross had a slightly more organisational role and tried to sort out the processes and make sure we operated well as a team. Those qualities back then, to me as quite a young engineer, were not so obvious.'

Exodus to Ferrari

The dream team looked like splitting up in 1997, when Brawn and Byrne went with Michael Schumacher to Ferrari. Tombazis no longer felt comfortable at Benetton, unsettled by the departures of good colleagues, so didn't need asking twice when he was offered the role of chief aerodynamicist at Maranello. 'Knowing that you're going to find Schumacher driving

Tombazis' first title win with Ferrari was the Constructors' Championship in 1999. In the late '90s and early 2000s, the Greek engineer worked on ever more sophisticated CFD simulations

Pictured with Rob Smedley during a 2007 test at Vallelunga, Tombazis spent a large part of his F1 career with Ferrari

there, [somebody] who would be giving you an extra few tenths per lap, is always an attraction,' says Tombazis. 'It's just more likely that you're going to end up winning.'

It was while at the Scuderia that he started to discover the real advantages Brawn brought to the table: 'The team there had huge organisational issues, and Ross managed to pull it all together. I appreciated Ross and his skills very much more in Ferrari.'

Tombazis, meanwhile, continued battling with CFD. However, the landscape was rapidly changing in terms of what the technology could do: 'When I arrived at Ferrari, they were already doing full car simulations,' he recalls. 'Admittedly, rather crude, and miles away in terms of accuracy and detail; they were really quite bad. We then hired some people. There was a particular person who came from America as a consultant from one of the CFD providers. He upped the game massively.

'It was around 1999, or 2000, when we did the first full simulation that I felt deserved to be called a simulation, where flow features were beginning to be half sensible. I'm not sure what number of cells teams have nowadays, I think something like half a billion, but for that first simulation we had about 30 million cells. It had maybe less than a tenth of the density of mesh it has now, but that was when it started actually getting semi-realistic.'

'I had always been intrigued by the rules and trying to contribute to the strategic direction of the sport… It was still a very high-pressure job, but in a slightly different perspective'

Launching the 2010 Ferrari F10 with Fernando Alonso, Aldo Costa (second from right) and Luca Marmorini (right)

Semi-realistic, perhaps, but still far from precise. 'Back then, it was a huge amount of trial and error,' admits Tombazis. 'You had to try to understand it to converge the solution as much as possible. Nowadays, it's a lot more scientific, there's very little left to chance.'

The use of full car CFD and the skills of Tombazis as chief aerodynamicist contributed to Schumacher and Ferrari re-writing the history books in the early 2000s. The German Italian combination was so successful that Tombazis recalls sleeping through the odd victory and only waking up to the national anthem. Winning became the norm. So much so that Tombazis started looking for a new challenge, and found just that at McLaren.

'It wasn't the happiest period of my life. I think I didn't perform that well either,' he says. Even working with Adrian Newey couldn't change that. 'I learnt a lot there. There were some extremely capable people, but it just wasn't my cup of tea at that time.'

After less than two years, Tombazis returned to Maranello. As chief designer, he celebrated the 2007 and 2008 world titles before things slowly unravelled. After narrowly missing out on two championships with Fernando Alonso, and a disastrous 2014 season with an inferior hybrid drive, the team underwent a major re-organisation, to which Tombazis fell victim.

Switching sides

After one season as head of aerodynamics at Manor, Tombazis switched sides in 2017. He initially worked as a consultant for F1's commercial rights holder. There, he met Brawn for the third time in his career. One of Brawn's primary tasks as managing director of motorsport at F1 was to improve the on-track spectacle, as part of a general push to transform its popularity.

Tombazis worked with Brawn's team on new regulations for 2021, which were not introduced until one year later due to the Covid pandemic. From a technical perspective, the engineer had come full circle: as a young boy, he fell in love with Colin Chapman's ground-effect cars, and now found himself making sure this aerodynamic philosophy returned to the grid.

He finally experienced the introduction of the regulations from the rule-making perspective as single seater technical director of the FIA, a role he attained in 2018.

'I was looking for a new challenge. I had one or two contacts with teams, but I also had contact with the FIA when my predecessor left the job. I had always been intrigued by the rules and trying to contribute to the strategic direction of the sport. That was a very interesting and different approach to what I had been doing. It was still a very high-pressure job, but in a slightly different perspective, and with a broader appeal.'

At the FIA, Tombazis initially only dealt with the sport's technical side; writing rules and ensuring they are adhered to. He has a comparatively small team to counter the armies of engineers employed by the teams, setting up that perennial struggle in F1 between the ingenuity of the competitors looking for loopholes, and the rule makers looking to close them.

'It's difficult,' admits Tombazis. 'We constantly seek to improve our ways of checking cars' legalities and so on. It's also quite difficult to discuss regulations and regulatory changes with the teams. We are obviously human in the FIA, and we make mistakes, but we absolutely do want the best for the sport, 100 per cent. I think we get it right more than we get it wrong.

'If you go to the team principals, they also want the sport to be healthy, but they also want their team to be winning, so that throws an angle to the argument. When they're saying we want to go in a certain sporting, or technical, direction, they have two equations to solve in their head: firstly, is it good for the sport? Secondly, is it good for my team? Is it going to give me an advantage compared to my rival?'

Public domain

After almost a quarter of a century on the team side of the discussion, Tombazis has developed a good instinct for sniffing out what competitors are trying to do.

'It smells all the time!' he suggests. 'All of this creates pressures and makes it quite challenging, but interesting as well from a human or political point of view, as well as technical. These challenges are what makes the job interesting. The pressure in a team is whether you're winning or not. It is huge euphoria when you are, and huge depression [otherwise]. We don't have those extremes in the FIA, but we do have a lot of pressure because, if we mess it up, it's all in the public domain, and it's always very easy to criticise the headmaster.'

In addition to the new regulations, Tombazis also took care of other matters: 'I felt there were a lot of things in how we were analysing and checking the cars that needed an upgrade, and I worked a bit on that.'

To help counter the numerical superiority of the teams, the FIA has increased its personnel in recent years. Ahead of the 2024 season, Tombazis was promoted to single seater director, with Jan Monchaux succeeding him in the single seater technical director post. Monchaux, another Imperial College alumnus, also comes from a team background, having worked in Ferrari's aerodynamics department at the same time as Tombazis in the early 2010s, before joining Audi Sport and then returning to Formula 1 with Sauber in 2018.

Tombazis and Ross Brawn present an early version of what went on to become the current ground effect F1 regulations

'We are obviously human in the FIA, and we make mistakes, but we absolutely do want the best for the sport, 100 per cent. I think we get it right more than we get it wrong'

With his most recent change in role, Tombazis has moved away from his technical grounding. Holding the top Formula 1 job at motorsport's governing body involves a lot of politics and organisation. He is also front and centre when it comes to fielding questions about F1's technical direction. Does he miss having a purely technical role? 'Yes, certainly,' he admits. 'I think there are pros and cons to both, but if you move up, you also have to let go of certain things. You can't expect to do everything you did before, but I have a very close relationship with the current technical director, the sporting director and the director of financial regulations and operations. We have a good team. We challenge each other and we don't always agree on things. So, I still get involved.'

Tombazis played a key role in finalising F1's new 2026 regulations, and this perfectly illustrates the responsibility of his current job. The changes made to the power unit are not only a modern technical solution, they are about getting engine manufacturers interested in F1. That goal was achieved when the likes of Audi, Red Bull Powertrains, Honda and Cadillac signed up to compete. However, recent discourse about returning to V10s and running them on sustainable fuel, which now appears to be cooling, demonstrates how complex the situation can be. Even before the first kilometre had been driven in a 2026 car, Tombazis was discussing with manufacturers whether they even wanted to stick with the next regulations for as long as agreed.

Mediating with teams is part of Tombazi's remit. Years of working on their side have helped him in his roles at the FIA

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Having been the first touring car series in the world to adopt hybrid in 2022, the move away from the technology and towards CO_2 reduction is a reflection of the BTCC's commitment to road relevance

Swapping sides

The BTCC is treading a new sustainability path, dropping hybrid systems in favour of 100 per cent sustainable fuel. **Racecar** ***investigates***

By DANIEL LLOYD

'This year, it will be very much more what we intended it to be originally: an overtaking tool, rather than a lap time generation tool'

Sam Riches, technical director at TOCA

Lap records are set to be broken in the 2025 British Touring Car Championship (BTCC) season. This year's cars are over 50kg lighter, following the removal of the spec, 48V, Cosworth hybrid system, but have lost none of their power. In pre-season testing, this helped produce lap times that unofficially beat the qualifying lap records at Brands Hatch, Croft, Snetterton and Donington Park. It was solid evidence that this year's crop of cars could be the fastest the BTCC has ever seen. They are also some of the greenest, using a new fuel made with sustainable bio hydrocarbons that the series says has reduced new CO_2 emissions by almost two thirds.

In 2022, the BTCC became the world's first touring car series to adopt hybrids. It was a move made to keep pace with the road car market, which at the time was leaning towards wholly or partially electrified powertrains. The system delivered a 30bhp boost through a motor integrated into the spec transmission at the front of each car. This replaced success ballast so, instead of the leading drivers' cars being laden with additional weight for the next race, they were given fewer seconds of boost and fewer laps on which to deploy it. However, the performance deltas ended up smaller than hoped, so the BTCC's governing body, TOCA, doubled the amount of power from the hybrid system for 2024 by adding an element of turbo boost (the battery was already at its peak potential). This gave each driver an extra 60bhp when they pushed the 'hybrid' button on their steering wheel.

That strategy only lasted one year though as, with two seasons of Cosworth's hybrid supply deal remaining, TOCA decided to ditch the heavy hybrid units altogether in favour of 100 per cent sustainable fuel.

The BTCC originally announced plans to use its 20 per cent sustainable content fuel from 2022 to the end of '26 but, with the price of the fuel dropping, and the other technology becoming less viable, it decided to strike while the iron was hot.

'We could have kept on doing [hybrid],' says BTCC chief executive, Alan Gow, 'but the avenue opened itself for a change to the fossil-free fuel. It was just a pragmatic decision. We couldn't do hybrid *and* [fully] sustainable fuel because it just costs too much money, so it was a cost thing.'

Turbo uptick

Once the decision was made to drop hybrids in 2025, TOCA needed something to replace the power boost with. Success ballast was out, not least because TOCA recognised that teams had become good at engineering around it, negating its purpose of equalising the field. Instead, the solution came in technology that had already been used to supplement the electric power boost in 2024. Doubling the potency of the spec Owen Developments turbocharger in boost mode by 200mb is designed to match the output of last year's hybrid package, and the feature has been called TOCA Turbo Boost, TTB for short.

'Everybody has dropped two boost steps this year because it allows us to end the additional boost that we're now using on the turbo,' says Tony Carozza, engineer at Alliance Racing, which runs the Ford Focus ST. 'Last year it was 30bhp from the hybrid motor and 30bhp from the engine, this year we've just doubled the boost [to 400mb].

'One of the biggest differences is the electrical power. With the old system, as soon as you hit the button, you had this instant spike of torque. We now have a bit of build time until we get to that peak power. But then you get the same the other end; when you release the button, it's a slow decay. The drivers don't feel the same kick in the back they felt with the hybrid system.'

When a driver pressed the hybrid button in 2024, the electric power and turbo boost would be applied simultaneously. The extra torque of the electric element led drivers to use the button in a particular way around a lap, but that is set to change under the new TTB functionality.

'Last year, they were using it as an outright performance tool through the corners to get quicker acceleration,' explains BTCC technical director, Sam Riches. 'If they got a couple of metres out of a corner, they would benefit at the end of the straight. This year, it will be very much more what we intended it to be originally: an overtaking tool, rather than a lap time generation tool. We hope it will lead to more traditional touring car manoeuvres, rather than he's just quicker than me. I think there will be fewer hybrid trains like we had last year.'

Carrozza agrees: 'Now, with the way the turbo ramps in and out, if you just go for a one-second push, you don't get that same spike. You're going to see bigger, longer, sustained pushes down the straight, rather than these short bursts.

'In theory, you wanted to use the hybrid at as low speed as possible, when you're in the lowest gear with the most acceleration potential, because that was the biggest lap time delta. Now, with the way the turbo works, you're going to be seeing three-second pushes as a minimum.'

The hybrid package included independent cooling systems: one for the motor and its controller unit, the other for the battery. Teams have blanked off the openings for these coolers and adapted their bumpers, while there is more space at the front to access parts like the splitter and headlights. The cooling set up, plus the battery, motor and ancillaries, weighed 55kg, with the

battery comprising just over half that figure. This saving has given team engineers more to play with in terms of weight balance.

'That's probably the biggest thing we've got, a re-balancing of the car,' adds Carrozza. 'It is going back to the pre-hybrid car weight, so it's not an unknown quantity. The tyre is different to what it was pre-hybrid, though, so that's a change. We've also removed this rotating, reasonably high inertia motor that was in front of the front axle, so that has helped massively with car dynamics.'

While every car has become 55kg lighter, TOCA has retained the rule whereby a rear-wheel drive car like the facelifted BMW 330i M Sport is 30kg heavier than front-wheel drive cars like the Ford, the Hyundai i30 N Fastback and the Toyota Corolla GR Sport.

Evolving role

Although the spec hybrid system it supplied has now gone, Cosworth is still involved in the BTCC. The company has continued to provide the standard electronics suite, including the Antares 8 ECU, which is also to be found in the LMH-spec Aston Martin Valkyrie.

'We would have loved to see it run to the end of the contract term and beyond,' says Tom Brown, head of motorsport programmes at Cosworth, 'but we worked hand-in-hand with TOCA; we are there to support TOCA, and the directions they want to take. In terms of what Cosworth got out of [the hybrid era], it was a demonstration of bringing that technology to market, so it served its purpose perfectly.'

'That's probably the biggest thing we've got, a re-balancing of the car. It is going back to the pre-hybrid car weight, so it's not an unknown quantity'

Tony Carrozza, engineer at Alliance Racing

This season, Cosworth is managing the TTB feature, converting the input from the driver's thumb on the steering wheel into the application of additional boost pressure at the turbocharger.

'TOCA provides us with regulations a team can operate up to, in terms of a wastegate target of how much boost pressure they can use,' explains Harry Spence, senior applications engineer at Cosworth Electronics. 'When a level of turbo boost was added in 2024, that gave us, and TOCA, a lot of understanding and learning. That fed forward into 2025, where the underlying algorithm we provide to TOCA is maintained all the way from a base calibration to post-race scrutineering.

'Ultimately, the algorithm was built for the hybrid system, but we have adapted and re-integrated it for a boost application. This year, teams have more control over the wastegate. Jumping an additional 200mb requires more duty and different terms of how to control that boost.'

The algorithm inside the Antares 8 considers a range of factors such as car brand, engine type and position on track. As was the case last year, the number of boosts each driver can execute is defined based on prior results. From a sporting perspective, these allocations haven't changed for 2025.

'There are several different aspects that build up and are fed into what is quite a complex model, that allows drivers to simply press a button,' adds Spence. 'Per TOCA's regulations, there are penalty delays if you push the button too early, as it was during the hybrid era. We've just migrated that to the boost implementation.'

Fuelling the future

The BTCC has not shied away from alternative fuels in the past, allowing teams to run diesel, bioethanol and liquefied petroleum gas (LPG). The current move to fuel that is made entirely of hydrocarbons derived from biological waste continues a long-standing collaboration between TOCA and fuel supplier, Haltermann Carless, which is now in its fourth decade.

Investigation into 100 per cent sustainable content fuel has been bubbling away inside Carless laboratories for several years now, but its application on track was only going to be possible once commercial viability had been achieved. According to Adrian Stuart, head of UK performance sales at Haltermann Carless, the cost of fully sustainable racing fuel was around £9 per litre four years ago, whereas now it is approaching half that.

Removing the heavy hybrid componentry from the front end has made the cars nimbler and given the engineers running them more options in terms of weight balance

Honda driver, Josh Cook, narrowly beat Ford driver Ash Sutton's qualifying lap record at Donington Park's National circuit during pre-season testing with the lighter cars

The amount of new CO_2 emitted during the 10-round season will fall by 55,000kg

Haltermann Carless has been investigating the use of biofuels for automotive usage since 2017. Work on a 100 per cent solution for use in the BTCC started three years ago, and has gone through 11 versions

The new fuel that has been developed for the BTCC is called Hiperflo ECO102 R100. Carless states it produces emissions of 38.74 gCO_2eq/MJ. This, based on analysis from TOCA, represents a 60 per cent reduction in the amount of new carbon BTCC cars are putting into the atmosphere. Additionally, Stuart says that based on a sample of 22 cars (last year's full-time grid; there are 24 this year), the amount of new CO_2 emitted during the 10-round season will fall by 55,000kg. Sustainable fuel does still release carbon into the air but, unlike fossil-derived petrol, this carbon is not being released for the first time once the engine combusts the fuel.

'The one we've introduced is our 11th iteration of a fully sustainable blend,' notes Stuart, 'though some iterations didn't go to the dynos, they were just lab blends, and didn't meet the definition of the specs.'

Those specs are laid out in Appendix J, an FIA document outlining technical guidelines for a range of racecar categories, as well as the requirements for an approved 'advanced sustainable' fuel. When Carless and TOCA developed the previous 20 per cent sustainable fuel, such FIA frameworks didn't exist. TOCA's goal then was to introduce something that would exceed the E10 fuel introduced to British roadside pumps in 2021. Its current aim is to keep pushing for ever more advanced sustainable fuels, based on the now-established regulations.

'The outlines say the fuel must contain a minimum of 50 per cent sustainable componentry,' says Stuart. 'The components then must adhere to the EU Renewable Energy Directive [RED] 2. Effectively, that ensures you're not competing with food crops; they have to come from waste, whether that's urban or agricultural.'

What sustainable components make up the bio hydrocarbons in the BTCC fuel is subject to intellectual property that Carless isn't willing to share. The EU RED 2 document lists 17 categories of waste item that could be used in an advanced biofuel, including animal manure, nut shells, wine lees and corn cobs. Carless buys in most components and refines them into bioethanol at its facility in Harwich, where the BTCC fuel mixture is processed, blended and produced.

'Because of the refinery capabilities, we can take those components and alter them further,' says Stuart. 'Whether that's putting them through distillation units and removing certain heavy ends of the component to make it fit better towards a motorsport application.'

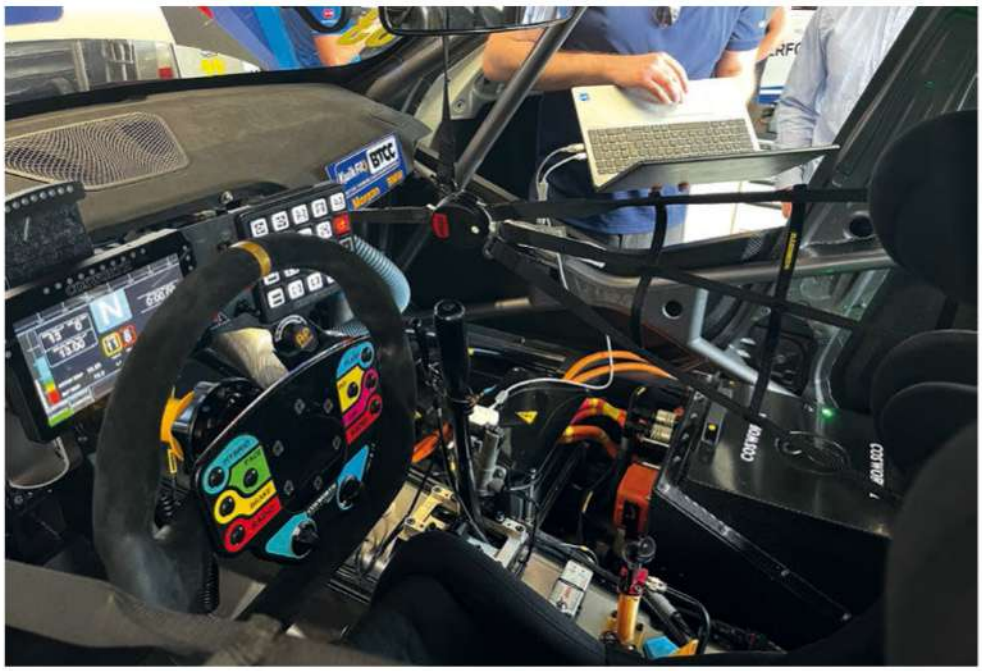
Target performance

A target for the new BTCC fuel is to at least match the performance of its predecessor. According to Riches, a test in race conditions at Silverstone last year, where an earlier version of Hiperflo ECO102 R100 was put in a Cupra Leon, produced slightly higher consumption of around two to three per cent. As further versions have been developed, consumption has reduced.

'In density, this looks like any other control gasoline fuel we've used,' says Stuart. 'There might be ever so slightly more consumption.

'In terms of the hardware, they might not be able to change, but a lot of the good stuff is hidden in the software nowadays'

Harry Spence, senior application engineer at Cosworth Electronics



Cosworth

Here's what the inside of a BTCC car looked like during the hybrid era; the battery is in the passenger compartment. The steering wheel has been updated for 2025 with the 'hybrid' button now labelled 'deploy'

The only reason being that the FIA definition of advanced sustainable fuel allows for a slightly higher oxygen content. A fossil-based fuel is capped at 3.7 per cent [oxygen], whereas for advanced sustainable material, the FIA outline a maximum of 7.5 per cent. Having spoken to the engine builders, it's negligible, they are expected to use the same amount of fuel over the course of the season.'

The higher the sustainable material content of fuel, the higher its price, although companies like Carless see that reducing as more bio hydrocarbons enter the market. In the BTCC's case, the cost of fuel has at least doubled for 2025. However, that substantial jump comes in the context of huge overall annual budgets. Various big numbers are floated around, but some teams are parting with half a million pounds on each car per season, even more at the bigger squads. In some cases, the fuel takes up around two per cent of the total. Additionally, some of the fuel cost is soaked up by the saving in not having a hybrid system, although teams still need to pay half their annual lease fee for the next two years as part of the deal to end Cosworth's hybrid supply early. Some teams are disappointed that dropping hybrids hasn't resulted in net savings but, when it's all totted up, the change has been small enough for them to swallow.

Successful integration

So far, the new fuel's integration appears to have gone smoothly. There were no glaring complaints during an official pre-season test at Donington Park in mid-April. The engine builders – Mountune, Neil Brown Engineering, Swindon Powertrain and M-Sport – were trialling different blends on the dyno last year, so had ample time to become acquainted, even if the season-starting iteration was only delivered in time for it to be used at the last few track tests.

'The fuel was developed as a direct replacement for what we used before, so was designed to be an easy change for us, and it was,' says Raphaël Caillé, managing director at Swindon Powertrain, which supplies the Hyundai teams. 'Of course, it's a little bit different. There are some changes in how we calibrate the ECU in terms of knock limits, lambda loops etc. But generally, it is a very similar situation.'

The biggest challenge for the engine builders over the winter has been preparing for a two-year homologation freeze on their 2.0-litre, inline, four-cylinder power units. The rule came into effect on 1 April 2025 and was implemented to save teams money.

'It cost us more, initially, trying to plan ahead,' says Dick Bennetts, whose West Surrey team introduced an updated BMW engine with NBE last year. 'Each engine builder has different views on what's the best way forward. Reliability is obviously important, so that's something we worked hard on.'

Of course, a freeze on hardware development is not what any engine builder would ever want but, when the grid almost dropped below 20 cars last year, such measures might be considered a necessary evil to keep the series buoyant.

'It doesn't mean development is finished. There are always things to do,' suggests Caillé. 'There are a number of internal components we have had to make a bigger step on this year, because that's it for the foreseeable future. The most important thing in BTCC is making everything work together.

'You are given a boost target, and it is then an efficiency job. The more you change in the spec, the more work you have. We have done a lot of fine tuning.'

Software development

Some features within the ECU, such as traction control, are locked away since the regulations prohibit them. However, there are also plenty of options for adjusting engine maps using the Cosworth electronics suite.

'With the boost increase, because of such a big step between base boost and deploying the boost, that increase requires a little more control,' explains Spence. 'In agreement with TOCA and the engine builders, we have allowed teams to control a different map for that different situation. In terms of the hardware, they might not be able to change, but a lot of the good stuff is hidden in the software nowadays. The range of capabilities on that ECU is down to the teams to deliver.'

To that Riches adds: 'They can play to their heart's content. Hopefully, it will give the engine builders time to stop chasing hardware and do things that are offered by Cosworth. The Antares is insanely powerful, I'm hoping they will all utilise it further.'

Behind the BTCC's headline-grabbing switch from hybrids to sustainable fuel is a desire to maintain the engineering challenge. Giving teams more scope for software modelling amid an engine freeze is aimed at doing that. A cheekier example is TOCA removing from the timing screens a column that shows when drivers are using their boost. Perhaps teams will now send spotters out to gather that information. If they do, they will need to be quick, because the cars will be lapping faster than they ever have before.

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Digging the dirt

Cross Car (XC) aims to build an accessible pathway for youngsters into the varied worlds of off-road racing

By **DIETER RENCKEN**

Ariel Wojciechowski / FIA

Quiz any professional racing driver about starting off in motorsport, and the chances are 10 to one that karting will be referenced somewhere along the way. Indeed, every Formula 1 champion of the past 30-odd years first twirled the wheel of a kart in anger, before progressing up the ladder by way of F4, F3 and F2, or the equivalent formulae of the time. Saliently, single-seater series are not the only categories to benefit from karting. Touring car, GT and endurance racing grids all feature alumni who starred in this grass roots discipline before rising above their peers.

Clearly, karting provides a perfect grounding for youngsters wishing to pursue asphalt circuit-based racing. Hence why virtually every major motor racing centre features a kart facility of some sort, whether it's indoor racing via arrive-and-drive offerings, or small-scale outdoor circuits that offer grand prix-type facilities. Factor in that such venues are, by definition, circuits without open traffic and it follows that five-year-old kids (or younger) are permitted to cut their racing teeth before even starting junior school.

What, though, about budding dirt artists, whose focus (or perhaps that of their parents) is aimed at loose surfaces and soft roads?

Consider this: most countries require competitors in such categories to hold a road licence, which means they are unlikely (or even able) to legally enter their chosen sport before the age of 16, at least. True, a number of rally stars started in karting before switching to dirt disciplines, but that is akin to a marathon runner training in track athletics for 10 years before making the switch.

It's no coincidence that most rally stars grew up in rural areas, learning to drive (and slide) cars on dirt at a young age.

Enter Cross Car (XC for short), the equivalent of a dirt track kart designed to provide the thrills, and safe spills, of dirt

For decades, karting has been the stepping stone into national and international racing but, up until now, there has not been a similar feeder for rallying and off-road racing. XC aims to change that

Cross Car MSG3 L2 fom motorsport gmbh.jpg

competition, yet accessible to youngsters, and with easy maintenance and low cost thrown in. The word Cross in the term says it all: think motocross, autocross and rallycross.

Emerging markets

Indeed, in line with FIA president, Mohammed Ben Sulayem's mission to double global motorsport participation by 2030, XC has been targeted by motorsport's governing body as the primary category for youngsters in emerging motorsport territories – that being Africa, Asia and South America. All are regions with a predominance of unpaved roads; Brazil's ratio is, for example, 89:11, while China sits at 66:34.

Where kart venues face planning and noise formalities, and require expensive asphalt topping, or massive halls, XC circuits can be graded by sympathetic land owners on open plots of ground in rural areas. Add a shed to provide garages and the odd 'yump' and waterhole and you have the potential for WRC and Dakar contenders in the making.

XC's roots reach deep into France's Mediterranean region. Around five decades ago, a group of enthusiasts decided to put remnants of Citroën 2CVs to use by installing their air-cooled flat twins and transaxles amidships in crude buggy chassis, suspended by the long-travel swing arms of their donor vehicles. The next step was to go faster and jump higher, so the cars became more sophisticated (read: costlier).

During the 1980s, multi-cylinder motorcycle engine / gearbox combinations replaced Citroën's whining twins, chassis became more complex and adjustable struts improved traction. Neighbouring countries recognised the appeal of XC (initially dubbed Crosskart or Kart Cross) as a cost-effective route into club motorsport, and so it gradually spread across Europe. By 2005, numerous European countries offered regional and national XC championships.

Recognising its popularity, in 2015, the FIA started working towards universal regulations to encourage participation across age groups and genders through reduced costs, yet without alienating existing competitors and constructors. By 2020, the classes were sufficiently consolidated for the governing body to host a European series, culminating in various XC competitions at the 2024 FIA Motorsport Games in Valencia.

Gradually, XC migrated out of its south western Europe heartland to territories new. India, for example, now has its own domestic championship, and it is not alone.

Class structure

Current regulations provide for two classes – Senior and Junior – using chassis with a minimum wet weight, without driver, of 345kg. Add a kitted-out driver (aged 13-16 for national / European championship events) and that rises to 410kg. Seniors (16+) come in at 425kg, with driver in full apparel onboard.

CROSS CAR TERMINOLOGY

XC	**Generic abbreviation for Cross Car, aka XCar**
XC Mini	**Level 1 chassis, 200/400cc**
XC Junior	**Level 2 chassis, 600-700cc**
XC Senior	**Level 2 chassis 600-900cc**
ACC	**Affordable Cross Car, for emerging regions (L1/L2, adapted to local preference)**

By specifying the same chassis for Juniors and Seniors (see glossary), a driver can readily contest both national and European events, and then upgrade to Seniors with the addition of a more powerful engine.

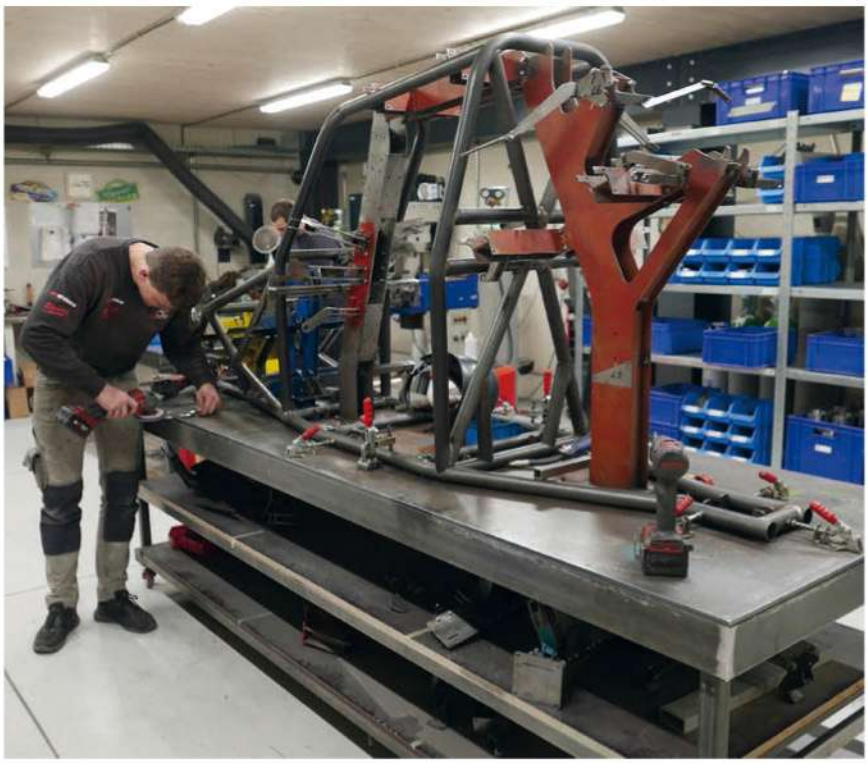
For Juniors, a single power unit is homologated, namely Yamaha's 690cc MT07, providing 54kW (72bhp). Seniors, meanwhile, have a choice of four PUs: Suzuki GSX-R600 (92kW / 123bhp), Yamaha YZF-R6 (88kW / 118bhp) and two versions of Yamaha's MT-09 (85kW / 114bhp or 88kW / 118bhp). The GSX-R600 engine, for example, dates back to 2011, meaning used engines are readily available, which can help to reduce costs.

Levelling up

Predictably, parents derive great pleasure from sharing the sport with their offspring, or live vicariously through them. Hence why the Level 1 (also known as XC Mini) sub-category was created (for ages eight to 12, maximum height 1.52m) and demonstrated during the

The Motorsport Games held in Spain featured XC racing for the first time and it proved to be a monumental success

Cross Car has been targeted by motorsport's governing body as the primary category for youngsters in emerging motorsport territories – that being Africa, Asia and South America



A Senior chassis being built by Belgian constructor, LifeLive. Both Junior and Senior categories use the same chassis

This is a Mini but chassis manufacture is free; it just has to comply with a series of technical and safety regs

Spaniard Pol Pujol (facing camera) built a worldwide reputation as a formidable XC engineer, known for finding creative solutions to improve performance. He worked closely with the FIA on the Affordable Cross Car programme

most recent Motorsport Games. It proved a hit amongst parents and spectators alike, despite (due to?) heavy overnight rain making the muddy track extremely slippery for the enthusiastic kids. Although not yet recognised as a regional series, the XC Mini class has already proven popular in Belgium and The Netherlands, attracting up to 30 entries at some race meets.

Powered by sealed, 200cc, 4.8kW (6.4bhp) Honda PUs from a single supplier to ensure equality and reliability, the target price for an XC Mini is €5000 (approx. $5800). Regulations for the Belgian series specify a dry weight of 130kg, but chassis manufacture is free within technical and homologation prescriptions, provided stringent technical and safety specifications are adhered to. Consequently, homebuilt specials abound, although proprietary chassis are available should parents lack the skills or facilities to undertake arguably the ultimate family bonding project.

Significantly, XC Mini chassis are also designed to accommodate 400cc Honda PUs, to enable drivers to upgrade to a 9.6kW performance unit as and when that class is introduced. The category is already finding traction in other countries, so the chances of a European – and potentially even world – championship are increasing. Imagine such an event, with karts racing on asphalt and Level 1 XCs on the circuits' access roads, all in the same weekend.

Construction workers

As XC's popularity grew, so chassis construction and engine tuning moved from back yards and home garages to backstreet workshops to factories, in the process creating openings for budding motorsport engineers whose spanner skills perhaps exceed their driving proficiency. An entire industry has now sprung up, with Europe currently boasting more than six constructors. An engineer who epitomises this emerging breed of XC engineer is Spaniard Pol Pujol (27), whose father, Jordi, won numerous Catalan regional titles.

Naturally, he involved his son in his endeavours, who freely admits to not being a natural racer. Still, he loved the sport so much that, from age 16, he dedicated himself to its technical and regulatory matters as he sought 'unfair advantages' for teams. Pujol's reputation spread, and he is viewed by XC teams as a committed and creative engineer, who pushes his interpretation of the regulations to the maximum.

Above all, his enthusiasm for XC is such that he continuously seeks the optimum cost-to-performance ratio, on the basis that affordability will increase XC's global popularity. As such, he cooperated with the FIA on its Affordable Cross Car project, announced in 2022 as one of the pillars in

The primary objective [of Affordable Cross Car] is for ASNs to build ACCs locally, thereby reducing costs, eliminating or reducing import taxation and developing local engineering expertise

To prove the ACC concept, the FIA tasked the Rwanda Automobile Club with building a car to demonstrate at its AGM. With help from Rwanda Polytechnic-Kigali, the project was a success, and the car went from there to race in Kenya

Ben Sulayem's mission. The primary objective is for ASNs (FIA-delegated national motorsport authorities) to build ACCs based on L1 or L2 chassis locally, thereby reducing costs, eliminating or reducing import taxation and developing local engineering expertise.

Target price

Blueprints are supplied to member clubs, who are then responsible for local manufacture, sales, back-up service and the setting up of domestic championships, either in-house or contracted. Target price is $5000 (£4000) for L1 Mini-based cars and $10,000 (approx. £8,500) for complete ACCs fitted with 200cc (L1 base) or 600cc, 45kW power units from popular local motorcycles. The idea being that used units and spares should be available from scrapyards to be recycled.

That figure still represents a lot of money in countries where monthly family incomes might only be around $800 – the pan-African monthly average – but an advantage of XC is that circuits can be cheaply laid out on open fields, and ACCs then made available on an arrive-and-drive basis. That way, it is not necessary to own and maintain your own ACC to be able to race one.

To achieve that cost objective, many of the components used were value engineered by Pujol to reduce costs as much as possible. For examples, doors are removable mesh 'gullwings', retained by bungee rubbers; driveshafts are standard Toyota Corolla; radiator / fan are ex-BMW 3 Series and the disc brakes on the interchangeable rear hubs are to delivery 'bike' specification. However, ASNs may also specify componentry to be used based on local availability.

This is all well and good on paper, but does the concept work in practice, in emerging countries with little or no local motorsport engineering experience?

To put that to the test, the FIA challenged the Rwanda Automobile Club (RAC) to build an ACC locally and demonstrate it at the governing body's Annual General Assembly and Prizegiving Gala, to be held in Kigali in mid-December. Giving the RAC a deadline of just two months was a tall order, but the Club commissioned the Rwanda Polytechnic-Kigali College to assist in building the 2.6m, 425kg ACC under the supervision of Pujol. Polytechnic student, Félix Ndayizeye, oversaw chassis welding and fabrication, with as many components as possible sourced locally.

'My responsibilities included welding and supporting our engineer from the FIA. After working together, we assembled the required parts. This shows Rwanda's vocational training programmes have immense potential,' Ndayizeye proudly told this writer afterwards. 'We've proven Rwanda can achieve great things, and we're confident about future projects,' he added.

Ahead of the FIA Gala, F1 world champion, Max Verstappen, viewed the completed ACC, commenting, 'I think it's great to have this opportunity, and I hope it stimulates these kids to become [drivers] or engineers in the future. No matter where in the world you come from, everything is possible.'

RAC has committed to building a further 10-15 ACCs locally by year end, and plans to launch a local ACC championship in 2026.

To further promote the concept, ahead of March's WRC Safari Rally Kenya round, the Rwandan-built ACC was transported to Nairobi and ran the opening Kasarani Special Stage, spectacularly driven by 14-year-old Kenyan karter, Cheche Ababu. Chief mechanic that day? Félix Ndayizeye from Kigali.

So impressed with ACC was Kenyan president, William Ruto, that he pledged support, urging the Kenya Motorsport Federation to collaborate with the Technical and Vocational Training Authority to make local production a reality. 'We want to create more opportunities for young Kenyans to participate in motorsport and, to this end, the government of Kenya will support the FIA's Affordable Cross Car project, which aims to develop motorsport talent in Kenya,' says Ruto. 'I thank FIA for providing free blueprints, which encourages local manufacturing while minimising costs.'

That XC is poised for expansion is evidenced by the number of manufacturers who produce over 50 chassis each per annum across the various classes and championship. These include France's Ligier Advanced Technologies (formerly Mygale) and Planet Motorsport; 2024 WRC champion Thierry Neuville's LifeLive operation in Belgium (see sidebar on p31), and Spanish constructors, Yacarcross, Speedcar and Camotos.

What karting has done for track series, XC hopes to do for WRC and cross country. That it will boost interest in motorsport is a given, particularly granted the FIA's mission to double participant numbers in emerging regions. The bonus is that XC will also build engineering talent, schooled and trained via locally-built XC racecars.

Affordable Cross Car blueprints are supplied free of charge to member clubs so safe, competitive cars can be built locally using readily sourced and affordable components

Interview with Thierry Neuville of Belgian XC constructor, LifeLive

Racecar Engineering: *When you first saw XC, how did it grab you?*
Thierry Neuville: XC has existed for a while on an amateur basis with self-made cars built in home workshops, but over the past 10 years it has developed into something more professional, especially when it comes to safety.

Six years ago I discovered XC and we [LifeLive, Neuville's motorsport company based near Spa-Francorchamps] contacted the FIA about developing the category in Europe. I was impressed by how safe, fast and exciting the cars are, and how cheap it is compared to anything else in motorsport.

RE: *When you started in rally, XC didn't exist. Do you think your career might have been different if it had?*
TN: There was nothing for young [racing] drivers before they got to 17, 18. Later there was autocross or rallycross but, before that, basically nothing. It was a big frustration for me because my parents didn't have the necessary funding to support me in karting, which is very expensive.

So I didn't have a choice, other than waiting until I was 17 / 18 years old. XC would have been a massive opportunity for me and others to start motorsport at a young age with small budgets. It provides grassroots motorsport with a ladder to the highest level in road sport, which wasn't the case for me starting from scratch to WRC within four years. I needed funding and backing from big investors. Now there is a ladder to climb.

RE: *Your company assisted with the Affordable Cross Car (ACC).*
TN: Yes. ACC is a great initiative. Everybody [at LifeLive] was excited to see something adapted for markets outside Europe where off-road is popular, but opportunities are low. We are excited about giving those people a chance to develop by creating opportunities for young people to launch motorsport and engineering careers.

Seeing the car we developed here in Belgium being driven in Rwanda was fabulous.

RE: *How do you see the ladder developing?*
TN: We have to highlight that XC can be driven from a young age, that there are various opportunities and options with different engines in the same chassis, so it's simple to create a number of different categories for people to become involved.

You now have a ladder with Juniors with small engines and Juniors with bigger engines. You then have Seniors with smaller or bigger engines, so you can have all these classes where people only need two or three chassis over a 10-year period to go from zero to hero.

Also, XC cars can be driven on gravel, on tarmac, on snow and ice, mud and in deserts. With XC anything is possible, but with karts you stick to tarmac. And because you don't need asphalt tracks to race, it's so much cheaper and simpler to get the infrastructure together.

RE: *Let's talk construction. XC chassis use the same type of tubing found in rollcages in rally cars. Correct?*
TN: Yes, and that's very important. XC are built to FIA technical regulations and standards, so there's no worry about safety. I would say the cars are basically over [specified] for their performance, especially in L1 and L2 Junior categories.

For the European Championship [where power and speed are higher] the regulations go further: FIA fuel cells, safety cells, removable steering, cockpit safety equipment for steering wheels, seats, harnesses, FIA foam for protection and so on. It's very similar to what I know from modern rally.

They are easy maintenance, too. There's basically an engine, chain, sprocket and some bearings. In the event of accidents, they are cheap and easy to repair. Probably the most expensive parts are the dampers and brake system, which are obviously high quality, and perhaps the engine.

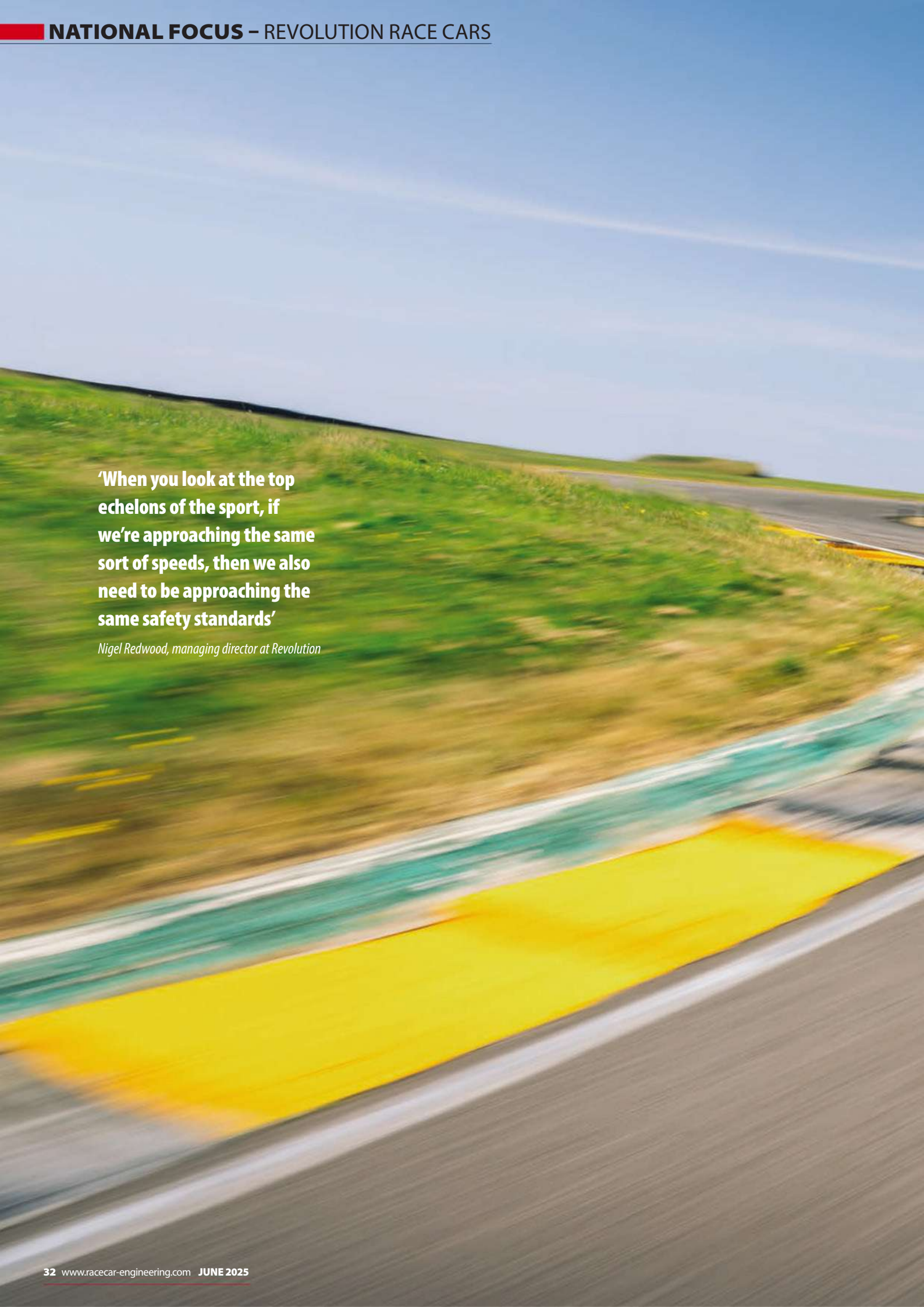
RE: *I don't know your familial situation, but would put your kid(s) into an XC?*
TN: My daughter is six and still a bit small, but I've put her in a car already. My son is 17 months and has sat many times in the car, so I'm sure that soon I will need to buy one, maybe two…

RE: *You can't build them yourself?*
TN: Yeah, but I'd still have to pay [smiles].

Racecar Engineering *thanks Rwanda Automobile Federation president, Christian Gakwaya, Pol Pujol, 2024 FIA World Rally Champion, Thierry Neuville, and LifeLive CEO, Raphael de Borman, for their assistance in compiling this article.*
Dieter Rencken is FIA executive advisor for road sport.

Thierry Neuville of LifeLive (left) explains the finer points of a Level 1 chassis to the FIA's Dieter Rencken

LifeLive CEO, Raphaël de Borman, and the author



'When you look at the top echelons of the sport, if we're approaching the same sort of speeds, then we also need to be approaching the same safety standards'

Nigel Redwood, managing director at Revolution

Revolution by design

With innovatively constructed carbon tubs, ingenious safety solutions and cars that lap as fast as LMP3s, Revolution is causing quite a stir on the national race and track day scene

By MIKE BRESLIN

Revolution was set up with the intention of bringing LMP levels of technology and safety to the club race and track day market. The company's 500 EVO is pictured here

There was a time when the first thing you'd look at after a car had been on track with a driver new to it were the lap times. These days, if you're operating in the burgeoning track day scene alongside your racing commitments, it's the expression on the driver's face that matters. If it's a broad smile, then it's a job well done.

That's the view of Phil Abbott, co-founder of Revolution Race Cars, at any rate, and it's understandable when you hear the UK-based constructor sells up to 75 per cent of its cars into the track day and 'country club' market. Don't let that fool you into thinking Revolutions are anything other than serious racecars. Indeed, the firm's top-spec 500 EVO has outqualified LMP3s in some races.

Radical revolutionary

Abbott has been involved in motorsport for many years, and is probably best known to many as the co-founder of Radical, which he set up with Mick Hyde in the 1990s. Revolution, which he founded alongside his race driver son, James, came into being in 2017, with the lessons learnt at Radical at the heart of its philosophy.

'Radical has been a great success,' says Abbott, 'but James and I just wanted to do something else, something a bit more "revolutionary", if you like. We wanted to bring the safety and quality of LMP-type racecars into the club world.'

With that in mind, one of the most obvious differences between Radical and Revolution is the type of chassis each firm uses. Radical, its SR9 LMP2 car aside, has always championed spaceframe designs, but for Revolution it's been carbon from the start.

'These types of cars are getting quicker and quicker because drivers demand that,' says Nigel Redwood, Revolution managing director. 'They want more fun, but they also want more speed, and more downforce. When you look at the top echelons of the sport, if we're approaching the same sort of speeds, then we also need to be approaching the same safety standards. Ultimately, to deliver that level of safety, carbon is the only route.'

The Revolution tubs certainly have the sort of stiffness you would expect from a high-end racecar, the company saying the torsional rigidity of its A1-R chassis is 4.9 times greater than a steel spaceframe (at close to 50,000Nm/degree). That's impressive, especially when it's noted that these are made wholly in-house, in a bespoke composite shop at Revolution's base in Yaxley, just outside Peterborough.

One well-known drawback to carbon is, of course, the expense, but Revolution has mitigated this to an extent, thanks to the use of a different manufacturing process to the prepreg method most chassis makers employ. This process is carbon infusion, which – very basically – involves using a vacuum pump to create negative pressure within a resin infusion bag, which then extrudes the resin through the fibres and into the bag to form the raw carbon piece.

Chassis tubs are made using a carbon infusion method, which reduces the amount of energy required by around 80 per cent. It is also a much faster process than prepreg

The finished carbon tub is said to be close to five times stiffer than a similar spaceframe design and is tested to FIA Article 277 safety standards

'We chose to go down the carbon infusion route for many reasons,' says Abbott. 'If you look at prepreg, for the manufacturing process you need an autoclave, which is all about high temperatures and high pressure; these days, they're pushing about 90psi. That shoves it into the mould, if you like, and compacts it. That mould then has to be something really serious, and you have to get it right first time; there's no sticking an extra tube in it if it goes wrong. Back in the day, we looked at doing it at Radical, but it was always rejected because of the expense.'

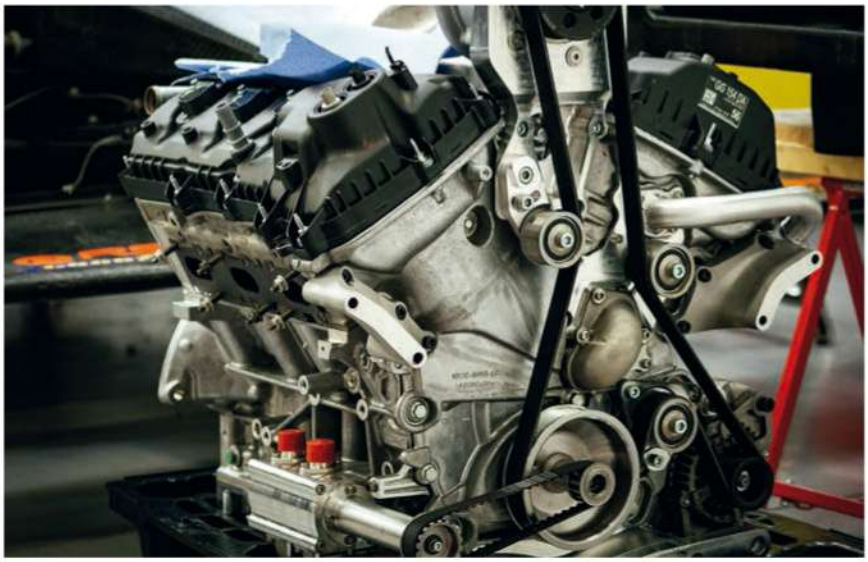
Prepreg is also far more time-consuming than vacuum infusion, as Abbott explains: 'We can put 4000g of fibre in in one go, whereas with prepreg you put much lighter layers in, like 250g, and then you're de-bulking, curing and repeating to get the same amount of fibre. For us, it's 1000g layers, and we put four loads in at once. Then vacuum it, infuse the resin into it and post-cure it at 60degC.'

Power down

The infusion method also cuts down on the amount of energy required for the process. 'With prepreg, it cures at 140-160degC, and you also have to keep it in a freezer,' Abbott continues. 'Otherwise, it will air dry. If you leave it on the bench for three weeks, it's gone. You need massive fridge boxes to keep the carbon reasonably in date. So, you've got power there, and then you've got all the heat cycles. Our process uses around 80 per cent less power than prepreg and the raw materials can be stored at room temperature.'

The carbon tub that's produced using this process goes through the same tests a prepreg chassis does, and the entire car is

Revolution's distinctive double halo is made from T45 steel and is designed to protect both driver and passenger in the event of a roll over and from flying debris. It is tied into a traditional rollover structure behind the cockpit



The 3.5-litre Ford V6 truck engine is tuned to give 500bhp and 410Nm torque. It is race prepared by RLM Racing and the dry sump oiling system has been designed so the 160kg unit can be located as low as possible in the chassis

tested to FIA Article 277 standards at Cranfield. It is, in fact, a conventional carbon tub, just made with unconventional methods.

The only real downside is the weight, as the end result is around five per cent heavier than a more mainstream carbon chassis. That said, Revolution has already shaved 25kg off the tub since it brought the procedure in-house and expects to make additional gains as the process is further refined.

Halo, halo

Perched atop the carbon chassis is one of the more visually striking aspects of the Revolution, its 'double halo', which is made from T45 steel and vaguely resembles a rollcage. Roll protection is just part of the reason for having it on the car, it mainly fulfils the original purpose of a Halo in ensuring the gap between the dash and the top bar is quite small, certainly not big enough for a loose wheel to enter the cockpit, while the supports offer protection for both the driver and a passenger. Someone riding shotgun, such as a driver coach, is not unusual on track days and Revolution racecars are designed to be genuine two-seaters.

Adding further safety is a regular roll hoop structure behind the driver / passenger, which can withstand 7.5kN of force, or 'the equivalent weight of 1.8 Asian elephants,' adds Redwood with a smile.

The dry weight of the Revolution 500 EVO is 900kg, which is a little heavy compared to similar cars, but then this includes a full race gearbox and a 160kg engine, rather than the bike-derived units commonly found in Radicals and the like. The car certainly has the power to nullify any weight disadvantage.

Before we get on to the engine, it's important to note that there are two cars in the Revolution range, the 427 and the 500 EVO. Both use the same A1-R tub and Ford V6 engine, but the EVO has a supercharger bolted onto its one, and a more advanced aero package. It also runs on 17 and 18in wheels, whereas the 427 uses 15 and 16in. The 500 was a development of the 427, so the latter can easily be updated to EVO spec. The 427 is priced around £150,000 (approx. $198,600) while the 500 EVO starts at £190,000 (approx. $251,600).

'There's quite a lot of restriction on the V6, because of exhaust emissions, so a lot of the porting is on the exhaust side of the head'

Phil Abbott, co-founder of Revolution Race Cars

Potent motor

The potent, 3.5-litre Ford V6 is a crate engine, more usually found in the manufacturers' F-150 pick-up range, and produces 500bhp with 410Nm of torque in the EVO (power-to-weight is 555bhp per tonne). Best of all, the unit does not need to be stressed much to hit this figure. This means the rebuild cycles are long, which helps keep the operating budget low for customers. Revolution recommends rebuilds at 5000km for the supercharged engine, but we're told some customers have run them to 10,000km without issue. For the naturally aspirated 427, rebuilds are advised between 8000 and 10,000km.

One of the main plus points of this engine, though, in a motorsport world where suitable powerplants are increasingly difficult to source, is its availability. 'It's in one of the top selling cars in the world,' says Abbott. 'It's also in the Ford Transit van in America. We asked Ford how long they would be available, and they said, if you look at the commercials, the van and the pick-up sell in South America, it's their biggest market. And they're not going to want electric in Venezuela and Brazil.'

The engines are prepared by RLM Racing, another company with its roots at Radical and part of a cadre of concerns Revolution has built close relationships with. 'RLM port the heads,' says Abbott. 'There's quite a lot of restriction on the V6, because of exhaust emissions, so a lot of the porting is on the exhaust side of the head. They also raise the profile and increase the duration on the cams, but we actually keep the compression ratio about the same for supercharging.'

Revolution chose supercharging over turbocharging for the 500 EVO, partly because of better driveability, but also because of the heat associated with the latter. 'There are pros and cons to both, but with a turbo you throw in so much heat, and then you've got to take it out,' says Abbott. 'The

turbo just heats the intake air. If you can pull the intake temperature right down, you get great driveability, great power, and you're not destroying the engine.'

The supercharger is supplied by Rotex and spins at 85,000rpm, which makes the car sound wonderful on track, although with track days in mind there are two exhaust systems available, one of which reduces the volume to 90db for circuits with noise restrictions.

One of the most effective, albeit less exciting, engine modifications has to do with the oiling system. 'We did something a bit revolutionary on the dry sump,' says Abbott. 'We took a bit off the bottom of the engine, so we can actually run it 50mm lower than anybody else has. Because, if you have a 160kg engine, you want to get it low.'

Shifting perspective

Power is transferred to the track via a six-speed gearbox made by 3MO, a French company that has developed the 'box specifically for Revolution and a well-known international single seater maker. It comes with a range of changeable ratios, while there's also paddle shift on the Life Racing steering wheel. Life supplies all the electronics, including the ECU, PDU and data logging. The steering wheel offers drivers five throttle map options, 10 traction control settings and five power steering settings. And that's just the start.

'From behind the steering wheel, the driver can adjust the engine modes,' explains Redwood. 'If it starts to rain, you can take power out of the engine, and things like that. There's a qualifying mode and a race mode, but we now also have a race automatic mode. What that does is it changes up the gearbox automatically, though you still have to change down yourself. You might ask, why would you do that? Because it means you're always changing at the perfect point in the powerband. We've had pro' drivers in the car and they say, "Oh no, I won't drive an automatic." Then, when they look at the data, they realise they've actually gone quicker.

'No matter what you do, we always find it's about a tenth quicker [than manual up shifting], because it's always changing at the perfect time in the powerband.'

The differential is limited slip, and the preload can be changed simply, and very quickly, via an adjuster on the gearbox. One full turn with an Allen key takes the unit from fully open to fully closed.

Mods and rockers

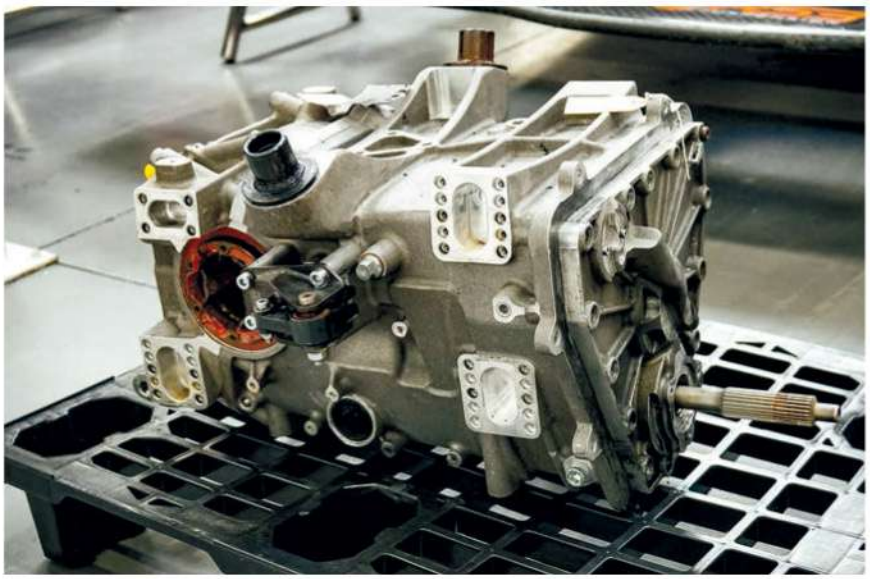
This simple adjustability is carried over into the suspension, which is double wishbone front and rear, with pushrods and rockers, while there are adjustable anti-roll bars at both ends. There has also been a big effort to make sure parts are interchangeable; the uprights, for example, are identical and symmetrical, so can be used on any corner of the car. This cuts down on the quantity of spares needed and also slashes the build cost.

Meanwhile, adjusting cambers is just a matter of changing shims. As for the dampers, these are three-way adjustable, and there are also third elements front and rear to help control pitch and heave.

The dampers are made by R53. 'They're really special dampers, it's probably the best damper company we've ever worked with,' says Abbott. 'On the second day of testing them, we didn't need a stopwatch. You could just see how much earlier the driver was on the throttle, how much control there was. It was amazing. These dampers just work, and they never stop working. They're fantastic.'

Tyres will largely depend on the championship a car is running in, but with the wheel size change on the EVO there are now more options for track day customers, largely because 18in is the tyre size of choice for GT3. Meanwhile, 320mm brakes – both front and back, again to cut down on the spares needed – provide 100bar (3*g*) brake pressure, or 2.6 tonnes of stopping power.

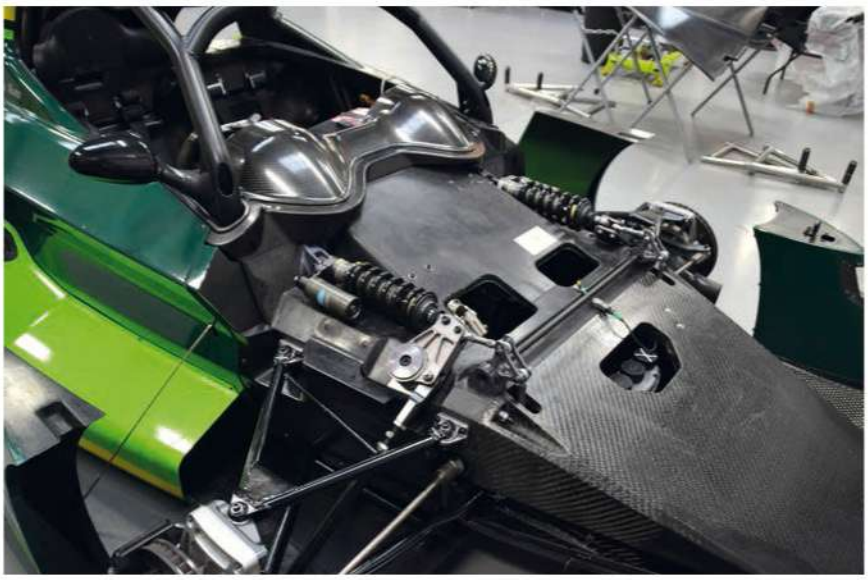
That amounts to an impressive longitudinal force of 2.5*g*. Lateral force is also impressive, at 2.2*g*, and this is down to a very effective aerodynamics package. This comprises a carbon rear wing on a swan neck mounting, and a carbon front wing. However,



The six-speed gearbox comes courtesy of French firm, 3MO, and offers a wide selection of switchable ratios, as well as the option for automatic up shifts. Multi-plate limited slip differential has a simple external preload adjustment

Life Racing steering wheel features data logging, paddle shift and multiple driver-adjustable modes and settings. The whole concept is to make the car a 'friendly' place, but with the capability to keep its drivers on their toes

The steering wheel offers drivers five throttle map options, 10 traction control settings and five power steering settings. And that's just the start



The double wishbone suspension is actuated by pushrods at the front and the rear. Many suspension parts, including the uprights, are duplicated across the car to cut down on the amount of spares required, and manufacturing cost

Brakes are 320mm x 25mm floating discs with four-piston calipers all round, again to reduce the number of spare parts needed. Third element dampers at both ends help control pitch and heave. Note track day-spec exhaust here

Carbon diffuser, floor and wings help produce 7000N of downforce at 100mph and 9500N at 150mph. A lot of work went in at the CFD stage to help keep aero attached when the car is sliding, making for a very driver-friendly racecar

Revolution's 500 EVO is not far off LMP3 figures when it comes to downforce, but it's not so much the overall numbers that matter… but where the downforce is useful

most of the downforce – 7000N at 100mph and 9500N at 150mph – is generated by the carbon floor and diffuser, which is a great benefit of a sports prototype layout for, as Abbott says, 'The more floor you've got, the more downforce you've got.'

The wings certainly still have a job to do though. 'The rear wing and diffuser work in harmony with each other, as the wing helps extract air from the diffuser,' explains Abbott. 'There's a good amount of upwash underneath the wing that extracts the diffuser. It clears all the rubbish out of the way, so the diffuser connects with it.'

The rear wing has been designed specifically for the EVO by Peter Watt, who has worked on many high-end motorsport programmes, including the Bentley Le Mans effort, and is also responsible for much of the CAD design work on the Revolution. The wing now has an expanded range of adjustment, but the front wing is not adjustable, although there are dive planes that can be tweaked if a change in aero balance is needed.

High-speed numbers

Revolution's 500 EVO is not far off LMP3 figures when it comes to downforce, but it's not so much the overall numbers that matter to the company, but rather where the downforce is useful. 'A lot of the numbers that we took notice of were around 100-120mph, because that's a high-speed corner for most people,' says Abbott. 'Also, the downforce goes up by the square of the speed. So, if you've got really good robust figures by 100mph, you just know that builds all the way.'

The aerodynamic design is largely courtesy of TotalSim CFD. 'The use of CFD has really translated into a friendly car,' says Redwood. 'The current model has done about 95 runs through CFD, and the result is if you get it a little bit sideways, the aero isn't falling off and you're spinning around. The aero just stays attached at different angles, and that all comes from working with CFD.'

Incidentally, the CFD has also shown that the double halo has very little effect on the aero performance, certainly none that a driver will notice. Whether it's had a detrimental effect on the car's looks is another matter but, with the public's acceptance of such structures in F1, it's doubtful many are bothered, especially with its obvious safety benefit.

Revolution does not take aesthetics for granted, though, and it works with Simon Cox, former head of design at GM and Infiniti, who is a great believer in using clay models, albeit on the back of lots of CAD work.

'Simon basically said, you can't simulate how the sun falls on a particular panel and shape,' says Abbott. 'The simulations are very good, but they're still a bit robotic. You can't simulate what you see and how normal light falls on the car. This is where clay models help.'

The company is now busy applying its design philosophy to an all-new car – the nature of which is secret for now, but look out for an announcement come the autumn. This is possible due to a healthy investment from the US last year, which saw new company, Cabotage Corporation Inc (an investment vehicle formed by private members motoring club, Classic Car Club Inc), Phil Abbott, Redwood and a small consortium of customers purchase Revolution. This also led to a management shake up, with Zac Moseley becoming chairman, Redwood taking his MD post and Abbott senior filling a new position of operations director while his son, James, is now head of product development. Both roles keep the Abbotts very much hands on.

Expansion chamber

Thanks to the recent investment, there's room for future expansion too, both in terms of the number of cars built and commercial property. At present, the company builds two cars a month, but it has the capacity to double this and could expand into bigger premises if it needed to further increase output. At time of writing, Revolution had built 57 cars, with 37 of them now in the US. Consequently, there are plans afoot to have a warehouse in America for spares and repairs.

Revolution also has dealers in South Korea, Germany, Portugal and Canada. While much of the business is for the track day market, these are still racecars, and there are a number of series around the world in which they compete. There's a Revolution Cup within the Prototype Sprint Series Association in the US, for example, while the cars feature heavily in the new multi-class Equipe Sports Prototypes series in the UK and Formula Prototype Challenge Canada.

'We just like bringing joy to people. When somebody tries our car for the first time, I always look at their reaction, and they're *always* smiling'

Phil Abbott

Abbott has much grander plans for the future: 'We want to be making and selling about 150 cars a year,' he says. 'At that point, the business is £20m turnover, and it looks, fundamentally, a different beast.'

A different beast that's similar in size to one just up the road, though, for Radical is also based in Peterborough. Which raises the question: is there a fierce rivalry between Revolution and Radical? 'To anybody who cares, there has to be, it's just what drives you forward,' says Abbott. 'It's the fear of failure, isn't it? You've *got* to succeed.'

That said, Radical does not define Revolution. 'The cars aren't really comparable any more, when you look at the technologies we're using,' says Redwood. 'In our marketing, we don't want to be saying this is equivalent to an SR3, or whatever it might be. We want to be heading totally in our own direction.'

And the direction Revolution is heading in remains firmly customer-driven, says Abbott. 'It's the whole experience, isn't it? Yes, we love making nice things in engineering, and clever things to make production better, but ultimately, it's got to give the right amount of pleasure. I think, in the final analysis, we just like bringing joy to people. When somebody tries our car for the first time, I always look at their reaction, and they're *always* smiling.'

The fact the lap times also happen to be super quick just makes it more satisfying. R

TECH SPEC: Revolution 500 EVO

Chassis
A1-R carbon monocoque made to FIA Article 277 regs; vacuum-infused production method; carbon bodywork

Engine
Longitudinally-mounted, supercharged, 3.5-litre Ford V6 with bespoke dry sump oil system. Power: 500bhp, torque: 410Nm

Suspension
Double wishbone (pushrods and rockers); cast aluminium uprights; R53 three-way adjustable dampers; third elements front and rear for pitch and heave control

Aerodynamics
Carbon front wing; carbon underfloor and rear diffuser; carbon rear wing

Transmission
3MO gearbox (transaxle supports suspension loads); paddle shift actuated; multi-plate LSD with external preload adjustment; switchable gear ratios

Steering
Adjustable EPAS with five assistance settings

Electronics
Life Racing, F1-type, steering wheel-operated control system; engine and chassis data logging; traction control with up to 10 driver-adjustable settings controlled by wheel speed and yaw sensors; five driver-adjustable throttle maps; Life Racing ECU and PDU

Safety
FIA-tested front crash structure and roll protection; collapsible steering column; FIA-compliant fuel cell; driver and passenger halo

Brakes
Front and rear: 320mm x 25mm floating discs; four-piston calipers

Wheels and tyres
Front: 8.5 x 17in (205/620 R17 tyre)
Rear: 11 x 18in (285/660 R18 tyre)

Dimensions and weight
Length: 4353mm
Width: 2000mm
Height: 1155mm
Wheelbase: 2660mm
Track: 1800mm (front); 1780mm (rear)
Dry weight: 900kg
Weight distribution: 45 per cent front, 55 per cent rear

Driver enjoyment is the key design priority at Revolution, which is understandable given that 75 per cent of its cars are sold into the track day and country club market

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Preparations at Sebring for the Type 61 Maserati in 1960 included Stirling Moss, who was the first to experience the car's excellence

Birds of prey

In 1959, Maserati startled the racing world with a new and unorthodox sportscar. Its rapid Type 60 and Type 61 models went on to become the stuff of legend

By KARL LUDVIGSEN

By the end of the 1950s, the front-engined racecar was dead, or at least dying. In Formula 1, mid-engined Coopers and Lotuses were winning, while sportscars were changing to engines behind their drivers and enjoying success. Despite this, it was still not quite clear whether a rear-mounted engine was essential in a well-designed sportscar. In the midst of this debate, a car appeared that challenged the emerging trend: the brilliant, and immortal, 'Birdcage' Maserati.

The creation of the Birdcage was evidence, if it were needed, of the astonishing resilience and creativity of the Officine Maserati in the late 1950s. This was the company that created the 250F grand prix car that helped Fangio to his 1954 and 1957 world championships, the beautiful and successful 300S sports racer and the incredible 450S V8 sports racer of 1957. A magnificent V12 engine had been created for the 250F, but this prodigality of technical innovation came at a heavy price; by the end of the 1957 season, Maserati's finances were in a parlous state.

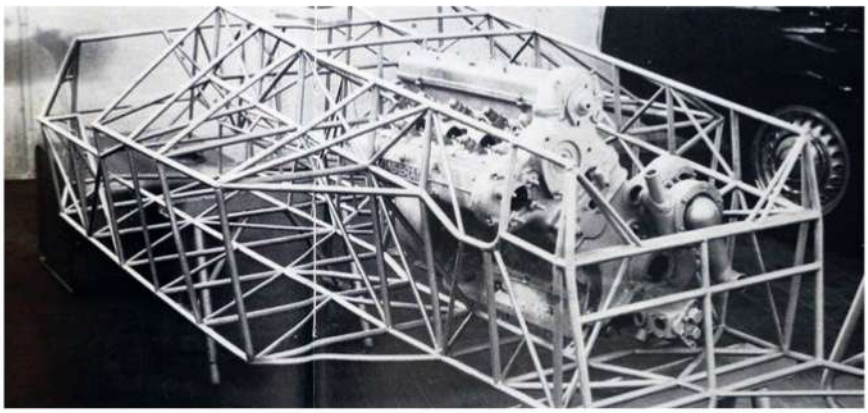
In 1958, operating under government administration to protect its financial integrity, the Modenese firm devoted more attention to its 3.5-litre GT car to help restore its cash flow. Grand prix racing was out of the question, apart from token entries in Fangio's final season. Its sports racers, like the 300S and the 200SI, continued to serve privateers, a category of competitor that had always received good value from Maserati, who (unlike Ferrari), was prepared to sell its first-string racecars to private stables. This was an important source of revenue for the company, especially the sale of spare parts.

Radical ideas

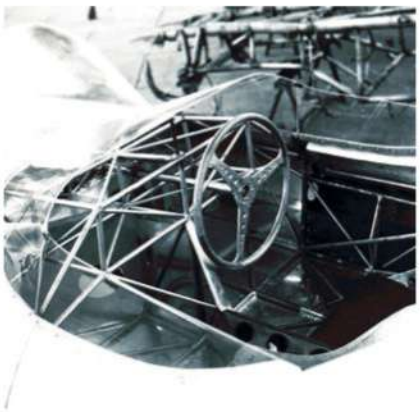
In October 1958, Maserati's chief engineer, Ing. Giulio Alfieri, began considering the creation of a new sports racer that could compete in the international 2.0-litre class, then an important category and one in which Maserati, from its 1953 A6GCS onward, had always been competitive. He had radical ideas for the configuration of the car and, in November, was ready to start making the first chassis to see how well it would perform. When tests proved satisfactory, Alfieri and his colleagues completed the design.

Early in December, the finished concept was presented to Maserati's chief, Omer Orsi, as a car that Maserati could build and sell to private owners. Orsi gave Alfieri the go ahead to build a prototype.

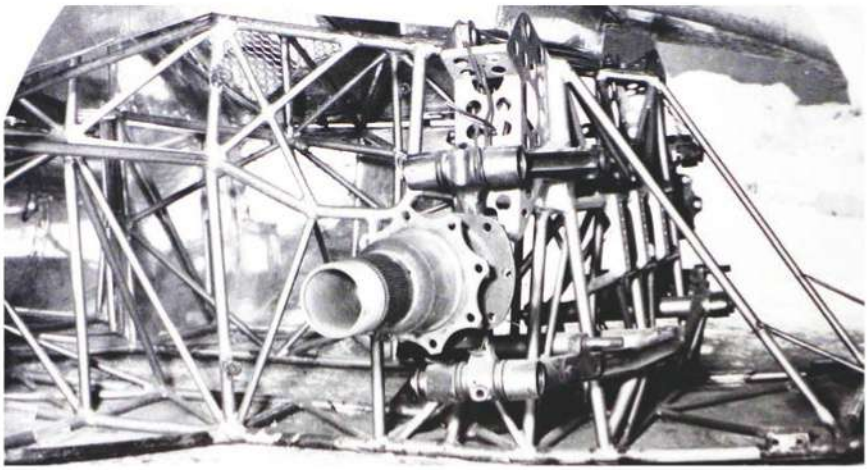
By May of 1959, the first 2.0-litre Type 60 Maserati was ready for testing in the hands of chief mechanic, Guerrino Bertocchi. On the public road from Modena towards Verona he found the new, as yet unpainted car very satisfactory. Its next test was at the Modena Autodromo on 19 May, with Stirling Moss at the wheel. Moss then tested



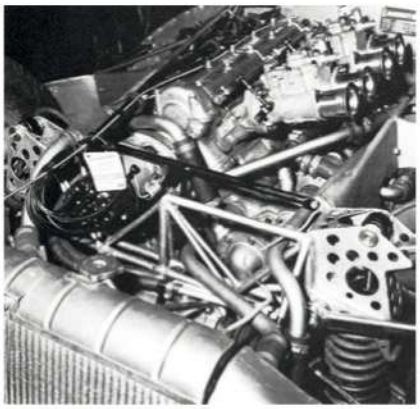
With its engine in place, the Type 60 / 61 Maserati's tubular frame shows its powerful rationality, although mechanics faced a challenge chasing breakages through the intricate network of small diameter tubes



As the first Type 60 takes shape, its fine structure contrasts starkly with the older frame behind



At the front of the Type 60 / 61 frame, traditional double wishbones were employed for its suspension



Anchors for the vertical dampers are seen at the front of the Type 60 / 61 chassis above its coil springs. Note how the engine is canted at 45 degrees

It was said at that time that a proper spaceframe should be built up around a parakeet: if the bird could fly away when the job was completed, it hadn't been done properly

Lightness was the watchword as the 2.0-litre Type 60 took shape in the Maserati workshop. Its low weight would prove to be a huge advantage

it at the Nürburgring on 4-6 June, breaking the lap record for 2.0-litre sportscars and offering some useful suggestions for the car's improvement.

Although Maserati did not intend to race the Type 60 itself, it felt a need to demonstrate its new model's capabilities to lure customers. Moss suggested the car be entered in a race for 2.0-litre sportscars at Rouen on 12 July 1959. There, he easily defeated the Type 15 Lotuses of Alan Stacey and Innes Ireland.

Odd looking as it was, with its bulging wings and trelliswork dash, the new Maserati was blindingly fast.

Bigger is better

Moss had already suggested to Alfieri and his engineers that they had in the 2.0-litre Type 60 the basis of a car that could compete in bigger leagues. They took up his recommendation and enlarged its four-cylinder engine to 2.9-litres, beefed up the drivetrain to suit and, in doing so, created the Type 61. That car soon showed it could take on, and defeat, the best its rivals could offer at a time when sportscars competed internationally to a 3.0-litre displacement limit. Fittingly, Moss was at the wheel for its first victory in Havana, Cuba in February 1960.

The striking feature of the new Maseratis, and that which won them the 'Birdcage' nickname, was the intricate frame, made of many small steel tubes welded together to form an elegant and idealised 'spaceframe'. The concept was originated by Giulio Alfieri, who had previously been mainly responsible for Maserati's engines. Chassis and transmission had been the work of young Valerio Colotti, who left Maserati in the meantime to set up his own Tec-Mec Studio in Modena. Alfieri's fresh point of view was responsible for the new car's novel frame.

Logical form

It was said at that time that a proper spaceframe should be built up around a parakeet: if the bird could fly away when the job was completed, it hadn't been done properly. This was the principle Alfieri followed in his design of the new Maseratis.

Ducting to and from the wide radiator had new and sophisticated passages in and under the powerplant

This overhead shot of Dan Gurney at the Nürburgring serves to remind us how much metalwork is lacking in and around the Maserati Type 61's cockpit

Minimised amenities is a hallmark of the Type 60 / 61, which took functionality to the extreme. A simple slot in the dashboard allowed vertical steering wheel adjustment

This shot clearly shows how the car's bodywork is attached to its tubular frame only where and when necessary. If it wasn't deemed necessary, it isn't there

Although obviously complicated, its construction was a technical *tour de force* by the car's stress-conscious designer and, when you look at it, completely logical.

Its premise was that the more tubes you use, the smaller they can be. If they are correctly placed, the lighter the structure will be for the same stiffness, or the stiffer it will be for the same weight, if that's what the designer is trying to accomplish. The ultimate iteration of this would be a near infinite number of tubes of near infinite thinness; a smooth, complete skin. In other words, a pure monocoque structure. The 'Birdcage' represented the closest approach to this achieved in a frame constructed of steel tubing, although the Mercedes-Benz 300SLR of 1955 also featured a complex and rigid spaceframe comprising numerous small diameter tubes.

Lacking experience in monocoque construction, but having craftsmen on hand skilled in the use of welding torches, Alfieri chose to use chrome molybdenum alloy steel tubes for his design. The main framework was formed from 20mm tubes diagonally braced by 12mm tubes. Where convenient, and helpful, the frame was strengthened by welding in steel sheet, notably along the front wheelhouses and under the front end. Stressed sheet was also used in the floorpan, over the door sills and in the propshaft tunnel, where there were fewer frame tubes. The original Type 60 frame was impressively light, weighing in at just 30kg (66lb).

Vital statistics

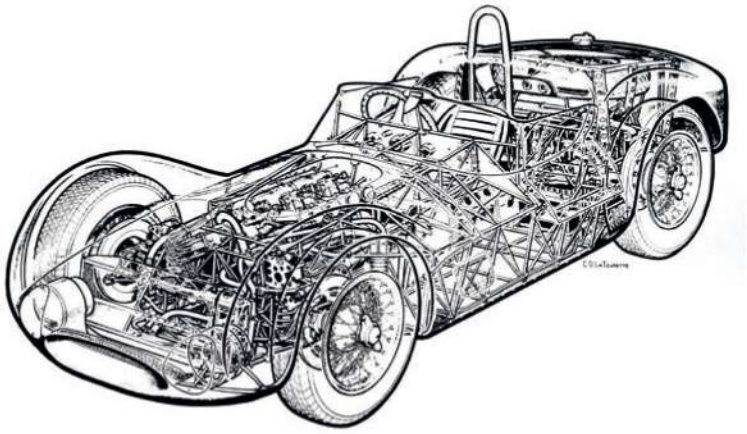
Because of the number of tubes, there was no need for extra body supports, and body skin was omitted where it served no useful purpose. Typical of this was the gap between the exiguous dash and the base of the 'screen.

In his selection of the Type 60 / 61's dimensions, Alfieri relied on principles that had been proven to equate to good handling. The new car's key parameters were identical to those of the 200SI: 2200mm wheelbase, 1250mm front track and 1200mm rear track. The Type 61 had 110mm less wheelbase and 50mm less track than the 300S it effectively replaced, reductions that contributed to the 200kg difference between the two cars. The new model came in at 570kg (1255lb) dry.

To lower both its bonnet line and its c of g, the car's inline four was canted 45 degrees to the right. The crankshaft centreline was offset to the left to keep the engine's weight centred. This required the propshaft be angled back to the right again as it ran rearward, though only slightly as the input shaft to the rear-mounted gearbox was also offset to the left. Proportionally, there was more room for the driver to the right of the driveshaft.

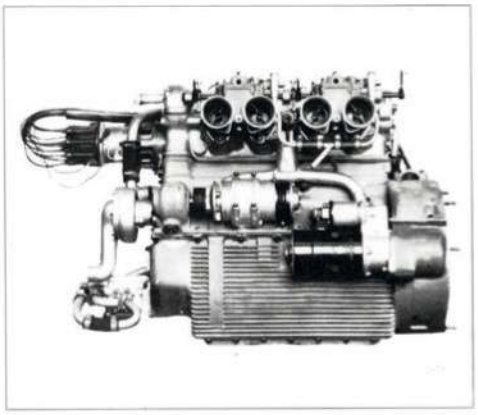
A traditional gate with reverse lock out took care of shifting the cogs in the rear-mounted, five-speed transaxle

The clutch pedal is mounted very close to the clutch disengagement, while the brake pedal controls separate master cylinders for the front and rear circuits, allowing brake bias to be dialled in to suit

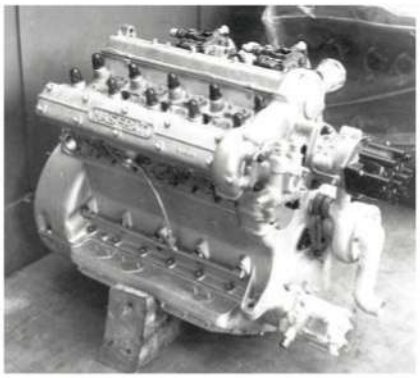


Clarence LaTourette's cutaway drawing is superb, considering the amount of detail, and the number of tubes, he had to contend with. The engine's ignition distributor is easily seen at the front

Inclining the engine made room for two twin-throat, sidedraft Weber carburettors and their induction ram pipes, 45mm on the 2.0-litre engines, 48 or 50 on the 2.9s



These two views of the Birdcage powerplant reveal its heavily finned sump, which sits level when the engine is canted over in the car. Note the exposed oil pumps of the dry sump lubrication system at the front and gear-driven dynamo and water pump



This is a 1959 2.0-litre engine built at the very beginning of the Type 60 project. 2.0-litre Type 60s are relatively rare, but remain very effective racecars

The Type 60 / 61's engine was derived from that of the 200SI, which in turn had been developed from the 150S. Its aluminium alloy block housed wet nitride iron cylinder liners and carried the crank in five main bearings. Massive main bearing caps, each held by four studs, restored the lateral strength that was lost by ending the bottom of the block at the crank centreline. A deep, cast aluminium sump was liberally finned on its left side and conformed to the engine's 45-degree slope.

Pressure and scavenge pumps for the dry sump lubrication system were exposed at the front of the sump. The single pressure pump drew oil from the reservoir on the left side of the engine bay and pumped it through a large filter, mounted to the frame next to the reservoir. Oil was drawn from the shallow sump by two pick-ups and two scavenge pumps, then returned to the tank via an oil cooler at the left of the water radiator.

Pipes and pieces

The four-cylinder 200SI engine let hot water out through a pipe at the front, between the cam drive gears. For the V8, the water piping of the 250F and 300S engines was adopted, so hot water exited though separate manifolding above the inlet valve seats (on the 'high side' of the angled engine), while cool water was pumped direct to the exhaust valve seats and guides by another manifold on the other side of the head vee.

With a compression ratio of 9.8:1, the Type 61 engine produced 255bhp at 6500rpm… [with] a strong torque curve that gave the engine enviable flexibility

With its single cylinder head placed at the same angle as the right-hand bank of the 450S V8, the Type 60 / 61 engine could afford to keep this new form of water manifolding.

An additional major change from the parent V8 was the abandonment of the elaborate roller finger cam follower that had come in with the 150S and spread to the 200SI and 450S. For his new engine, Alfieri reverted to the simple, light, space saving finger follower that had been proven on all Maserati's twin-cam sixes. In the latter engines, it was combined with coil springs, while in the new four it worked with hairpin-type springs for the first time. Valves were inclined at a 76-degree included angle: 37 degrees from the vertical for the inlets and 39 degrees for the exhausts.

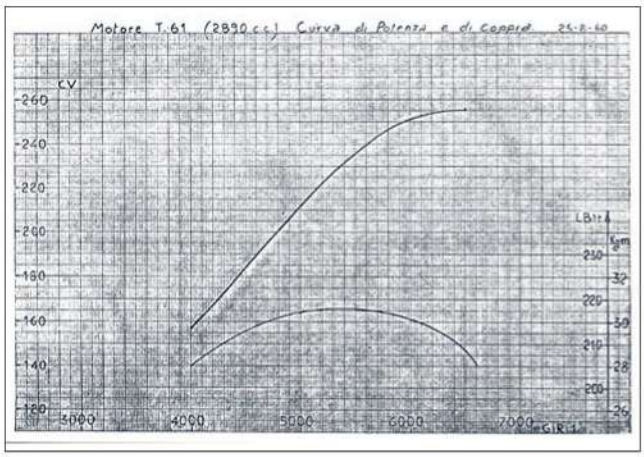
Weber 45mm twin-throat carburettors were used on the Type 60 engines, protruding high from the bonnet for the straightest possible airflow path into the ports. On the Type 61, the carburettors (either 48 or 50mm) were angled down under a more modest bonnet bulge. The tuned, scavenging exhaust system was of conventional shape.

To enlarge the capacity of the engine, its bore was increased as much as the block and liners would allow, to 100mm, and the stroke increased to 92mm for a cubic capacity of 2890cc. Achieving the latter required the casting of a new cylinder block 10mm taller (an attempt to lengthen the stroke to 95.5mm to bring displacement to 2985cc failed when the test engine destroyed itself on the Maserati dynamometer).

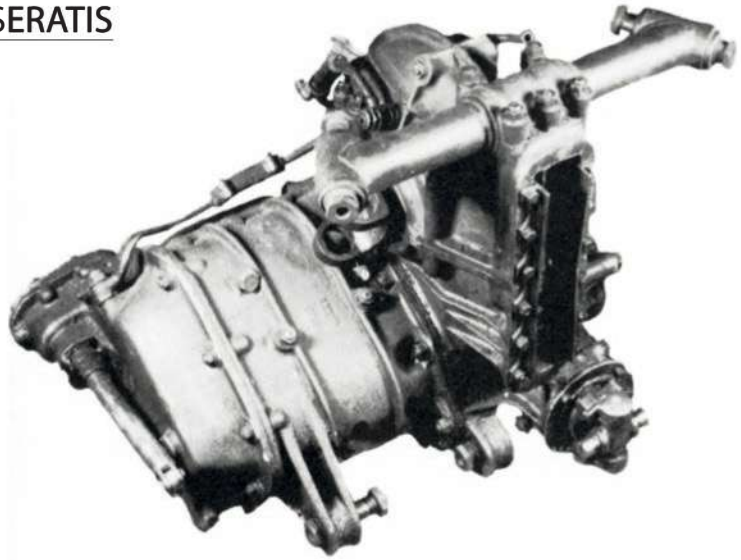
Enviable flexibility

With a compression ratio of 9.8:1, the Type 61 engine produced 255bhp at 6500rpm. Its torque reached a maximum of 31.6kg/m (229ft.lbs) at the 5000rpm peak of a strong torque curve that gave the engine enviable flexibility. Transmitted through a multi-plate clutch in unit with the engine, it drove an engine-speed propshaft to the rear-mounted transaxle that had been a Maserati feature since it was introduced on the company's 1954 grand prix car.

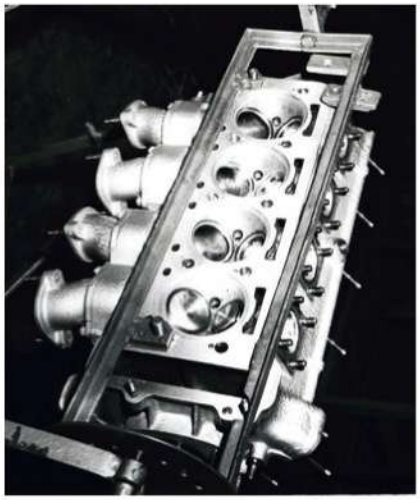
In the compact transaxle's transverse-shaft arrangement, its gearchange shafts lay to the right of the input bevel gears and its spur output gearing to the ZF differential. Rugged dog clutches engaged five constant-mesh



Power and torque figures from a dyno run on 23 August 1960 are graphed for the 2.9-litre Type 61 engine from 4000 to 6700rpm, showing a peak output of 255bhp



Viewed from the front, the Maserati transaxle's sliding retainer for the front-placed de Dion tube is visible. Connection for gear selection is at the front left



Dual ignition brought the spark plugs closer to the centre of the combustion chambers in the engine. Head castings included inlet port extensions

A colour cutaway reveals the Birdcage's rear suspension and the Maserati-made disc brakes to Girling designs

forward gear sets in the Type 61, while a latch in its short-travel gate blocked off reverse. This layout provided the right-hand shift that was more familiar to American customers.

Using this transaxle meant Alfieri could also keep the de Dion rear suspension that was introduced on the 250F. Its axle tube ran forward of the gearbox, laterally located by a steel-sided slide in the front of the transaxle casing. Parallel trailing arms guided the wheel hubs. High above the axle shafts, the rear transverse leaf spring was carried in pairs of rollers to augment roll resistance at the rear. Separately mounted, on drilled webs, were tubular dampers, initially by Girling, though Konis were a more common fitment later.

Rack and roll

A novelty for Maserati was the use of rack and pinion steering gear, mounted ahead of the front wheel centres. It actuated forward facing steering arms through short, remarkably thin tie rods that preserved traditional Maserati steering geometry.

The front suspension used components from recent Maserati grand prix cars. Wishbones were parallel, with the top arm substantially shorter than the bottom one. They, and their concentric coil damper assemblies, were hung from drilled pylons, with a small diameter anti-roll bar mounted below and forward of the lower wishbones.

The Type 60 / 61's brakes marked another major step forward. Maserati took up an experimental Girling design, which had been tried by Ferrari on its coil-sprung F1 car in Morocco at the end of 1958, but dropped in favour of Dunlop discs. The deep-set Girling disc kept its rubbing surfaces out in the airflow, while its unique, three-cylinder, fully machined caliper was made by Maserati to Girling's design. Front discs were 355mm in diameter and 315mm in the rear. Separate master cylinders for the front and rear circuits allowed for adjustable brake proportioning.

Borrani wire wheels were 16in, with 4.5in Duralumin rims fitted at all four corners. Normally, the tyre fitting was Pirelli Stelvio 5.50 x 16s at the front and 6.50 x 16s at the rear, though some cars were shipped to America with 5.50 x 16 Dunlop D5s on the front wheels and 6.00 x 16 Pirellis on the rear. According to Maserati's chief mechanic, Guerrino Bertocchi, this was a factory recommended combination, though one American team chose to disregard that and combine Firestone tyres at the rear with Dunlops or Pirellis at the front.

Low and compact, the Type 60 / 61 wrapped its body tightly around the wheels as an asset to its speed. Alfieri verified the shape's efficiency with clay models in Maserati's wind tunnel. Claimed top-speed capabilities for the small and large Birdcage versions were 168 and 177mph respectively, closely approximated using high final-drive ratios in the transaxle.

Under racing conditions, the cars consumed about 40 litres per 100kms from a 120-litre fuel tank, though smaller tanks were made for cars competing in the short sprint races more common in the United States.

The ex-factory price of a Type 61 Maserati when new was the lire equivalent of $10,800. By the time an American customer had paid freight and duty, they would have spent some $12,000. A customer in Europe, on the other hand, might have paid as little as the equivalent of $9000 for their car, the cost to an authorised Maserati distributor being $8000. Records tell us that the average

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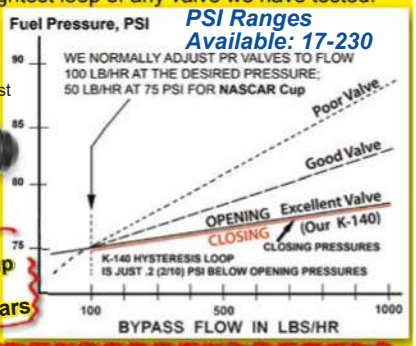

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Testing the first 2.0-litre Type 60 at the Modena Autodromo on 12 May 1959, Stirling Moss 'thought it was fantastic – ridiculously light'

Moss persuaded Maserati to let him race the new car at Rouen in France on 12 July 1959. Starting from pole, he was never passed over 32 laps

With a more steeply sloped windscreen, Swiss racer Gaston Andrey won his SCCA class championship in Mike Garber's Birdcage in 1960

At the end of 1959, Californian, Joe Lubin's, Type 61 was raced effectively by Bob Drake, including in events at Nassau in the Bahamas

Chiefly in Europe, the 2.0-litre Type 60 mastered its class, with Odoardo Govoni its principal advocate, scoring numerous successes behind the wheel

Driving a Type 61 owned by Briggs Cunningham and prepared by Alfred Momo, Walt Hansgen took no prisoners in America's 1960 races

revenue per car received by Maserati from the sale of the first 21 Birdcages was the equivalent of $11,800.

Perhaps unsurprisingly, early races revealed some durability issues. Two of the new cars broke their de Dion axles at Nassau at the end of 1959, so a stronger design was produced and retro fitted. After failures at Sebring in March 1960, the rear hubs were strengthened and the main bearings increased in diameter from 60 to 65mm.

Race history

Type 61s enjoyed many successes in North America. They won the SCCA's Class D Modified championship for 3.0-litre sportscars for Gaston Andrey in 1960 and Roger Penske in 1961. Drivers such as Jim Hall, Bob Drake, Walt Hansgen, Jim Jeffords, John Fitch and Carroll Shelby all raced the new Maseratis with great success for private teams. Bill Krause used one to defeat all comers, including Stirling Moss in a mid-engined Lotus 19, at Riverside in October 1960.

Although the Birdcage Maseratis easily led all the international events they entered, their record of success was spotty. In 1960 and 1961, international race entries were made by a Goodyear-backed American team, Camoradi USA, founded by Miami car dealer, Lloyd 'Lucky' Casner. Camoradi owned the cars, engaged the drivers and made the race entries, while Maserati took care of preparation. With drivers such as Stirling Moss, Dan Gurney, Carroll Shelby and Masten Gregory, Camoradi seemed well equipped for the 1960 season. However, finances of both Camoradi and Maserati did not extend to thorough testing of the new cars, with the result that in long-distance races they often suffered retirements. The team brought a superbly streamlined Type 61 (actually the original Type 60, rebuilt) to Le Mans in 1960 for Chuck Daigh and Masten Gregory. Again, it easily outpaced all other competitors, both in practice and the race, but ultimately retired.

Although the Birdcage Maseratis easily led all the international events they entered, their record of success was spotty

A noteworthy, and noble, exception to this record was the performance of the Type 61 at the Nürburgring. There, in the 1000-kilometre race, Camoradi Birdcages were successful in both 1960 and 1961. In the first year, the driver pairing was Moss / Gurney, one of the greatest duos of all time, and in the second year victory went to Masten Gregory, partnered by 'Lucky' Casner himself.

Move to mid

Maserati, in the meantime, elected to build mid-engined cars, starting with the first test of the Type 63 in December 1960. It is never rewarding to contemplate 'what if?' but the superiority of the Type 61 over its rivals was so great that it would probably have swept the board in international racing in 1961, had Maserati concentrated on its development instead of becoming embroiled in the selectively successful Type 63 / 64 adventure, which only matured in America.

In all, 22 Birdcage Maseratis were produced. 11 were built in 1959, seven of them Type 61s. In 1960, nine were produced,

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This Type 61 Maserati was entered by Camoradi USA and driven successfully by Moss and Gurney to win the Nürburgring 1,000 Kilometres in 1960

Minnesotan, Don Skogmo, raced his Type 61 successfully from 1961 through 1963, largely in the American Midwest

Beautifully balanced, well braked, easy to steer and immensely satisfying to drive, the Type 61 'Birdcage' Maseratis continue to give their owners great satisfaction in vintage racing all over the world

two being Type 60s, and two final Type 61s were made in 1961, together with five new engines. The production total for each type therefore stands at 16 Type 61s and six Type 60s (with one Type 60 rebuilt as a Type 61 by the factory, subsequent to most of the other 2.0-litre Birdcages).

Profitable exercise

Researcher, Joel Finn, says that by 1961, Maserati had spent the equivalent of some $240,000 building the Birdcage racers, with the cars and their spares realising $248,000 for the factory. With further revenue

Intending to provide a speed margin at Le Mans, Maserati produced this streamlined version of its Type 61

In a modified version of the low-drag Maserati Type 61, Lloyd 'Lucky' Casner (shown) and Jim Jeffords raced at Le Mans in 1960. The car was devilishly quick, but reliability issues meant they did not finish the race

forthcoming from the sale of additional spare parts to privateer race teams, the Birdcage programme was deemed a profitable exercise for Maserati, justifying the argument of Giulio Alfieri and the acquiescence of Omer Orsi.

Beautifully balanced, well braked, easy to steer and immensely satisfying to drive, the Type 61 'Birdcage' Maseratis continue to give their owners great satisfaction in vintage racing all over the world. Fortunately, enough of the very limited production runs of the Type 60 and Type 61 cars survive that today's vintage racing enthusiasts regularly have the chance to enjoy these iconic Maseratis that were, in their day, the fastest car of their kind. That's a Maserati tradition well worth applauding.

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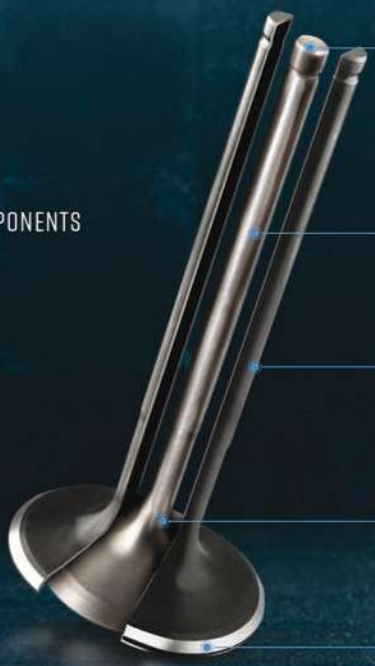

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Mixing messages

Racecar *investigates the latest advances in composites technology and processing*

By LAWRENCE BUTCHER

The most common composite production process in motorsport requires the use of autoclaves. These giant machines consume a great deal of energy, so more efficient alternatives are appealing

Composites have formed the backbone of racecar construction for the past four decades and are also making it into mainstream automotive applications. The reality is that, while motorsport is a significant user of composite materials, particularly carbon fibre, its use pales into insignificance when compared to other industries, especially aerospace. For this reason, many of the new developments in the materials and processing technologies come from sectors such as this.

Carbon fibres are produced by the controlled oxidation, carbonisation and graphitisation of carbon-rich organic precursors in fibre form. The most common precursor is polyacrylonitrile (PAN), although fibres can also be made from pitch or cellulose. By varying the graphitisation process, either high-strength fibres (processed at about 2600degC) or high-modulus fibres (processed at around 3000degC) can be made, with those of varying characteristics in between.

Band width

High-strength fibres, as the name suggests, have excellent tensile strength but tend not to be very stiff. Conversely, high-modulus

The starting point for carbon composites, yarns spun from thousands of individual fibres. Shown is a roll of one of Toray's products

fibres are stiff but at the expense of ultimate tensile strength. Fibres are grouped according to the modulus band in which their properties fall. These bands are commonly referred to as high strength (HS), intermediate modulus (IM), high modulus (HM) and ultra-high modulus (UHM).

For example, the current strongest carbon fibre available on the market is Toray's recently developed T1200, which has a tensile strength of 8GPa, but a modulus of 317GPa. Compare this to the company's M60J high-modulus fibre, which has a modulus of 588GPa, but a tensile strength of only 3.8GPa.

Development of these fibres is constantly advancing, and the latest offering from Toray is its M46X, sporting a tensile strength of 5GPa and a modulus of 360GPa, placing it on a par, strength-wise, with commonly used high-strength fibres such as T800. According to Toray, this blending of properties has been achieved through precise control of the crystalline make-up of the graphite within the fibres, to create very fine, highly orientated crystals.

The fibres are then laid out in controlled conditions, the process used depending on the application of the part being made

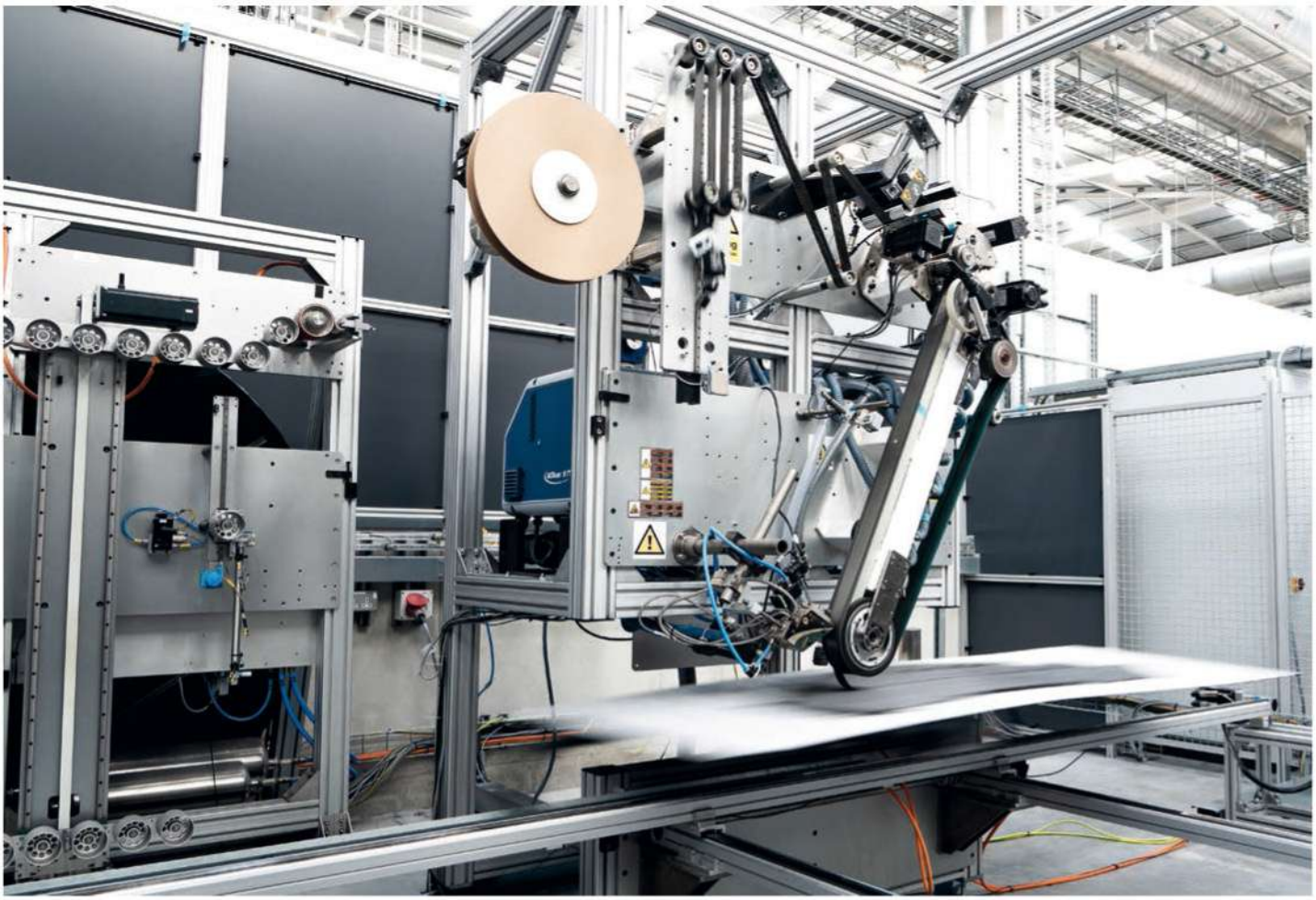
The orientation of fibres throughout the plies of a lay-up have a huge influence on a component's final mechanical properties

Surface treatments

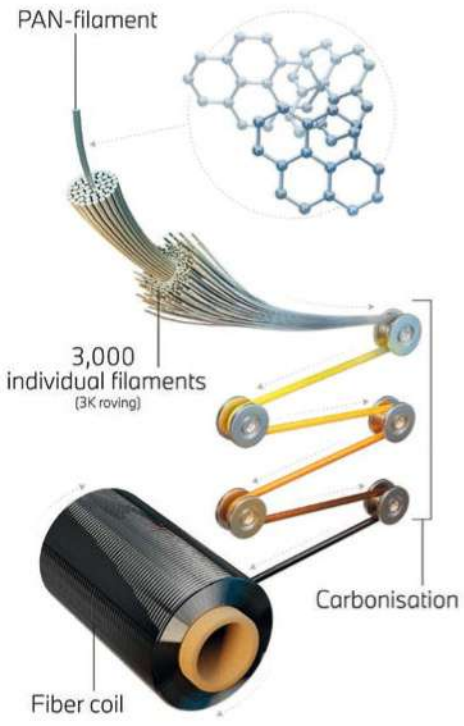
A key contributing factor to the properties of carbon fibres, once they are encased in an epoxy matrix, is surface treatment. All fibres are subject to surface treatment, otherwise they would not bond effectively with the matrix. These treatments can enhance bonding by both physical and chemical means. For example, treatments can remove any weak layers on the surface of the fibres to provide greater contact with the polymer matrix, or create surface porosity to allow the resin to penetrate the fibres.

A coupling agent can also be applied, which chemically bonds to both the fibre and resin in a process known as sizing. The relationship between surface treatment and sizing is a close and complex one and, understandably, is something of a trade secret for materials suppliers. Fortunately, there are many standard resin systems on the market

Those properties are entirely dependent on the application of the part. Some need high strength, others focus on heat resistance, while some components are required to withstand specific load paths



McLaren's ART (Automated Rapid Tape) system automatically places prepreg tapes at a rate that makes composite part manufacture compatible with low volume production car building



Schematic produced by BMW to show the process of carbon fibre production for use in automotive applications

and most fibres are processed in a way as to be compatible with these to allow for consistent curing control.

When it comes to the development of new resin systems, such as those designed to cure at lower temperatures, or differing manufacturing techniques other than using pre-impregnated carbon fabric (prepreg), issues can arise.

Beyond improving bonding, surface treatment of the individual fibres can also help improve other properties. Recent work has been undertaken on applying metallic plating to fibres, such as nickel, to increase their ability to block electromagnetic interference (EMI), making them particularly useful in applications where high levels of this exist, such as EV powertrains.

Fabric types

Once processed, the individual carbon fibres are spun into tows, or rovings, which form the basis of the fabrics used to make parts. These tows are classified by the number of filaments they contain, 1K, 3K and so on, denoting the number of filaments in thousands.

It is worth mentioning at this point filament winding, which, as the name suggests, involves wrapping carbon filaments around a mandrel to form cylindrical shapes. This process is often used in the construction

There have been some interesting developments in composite weaving technology to address specific challenges

of pressure vessels, and is particularly relevant here given the various recent efforts to deploy hydrogen in racing (see sidebar on p56).

By far the most common type of carbon fabrics, however, are twill and plan weaves, and the orientation of the various fibres in these can be varied to adjust their properties. Unidirectional weaves, for example, all run in one direction, while bi-directional weaves run in two directions, and so on. Each of these different weaves has its use. Unidirectional tapes are often used for reinforcement of specific areas, while woven fabrics are good at conforming to complex geometries.

There have been some interesting developments in composite weaving technology to address specific challenges. One example is a project between ESAIT, the French National Institute for Textile Engineering, and Airbus, to create a method of weaving fabrics that incorporates 90-degree corner radii. The solution allowed for fibres to be woven in three dimensions,

rather than the more regular two, with the final form impregnated with resin via a resin transfer process. The end result removed the need for additional aluminium inserts at the corners, so reducing the complexity of the part, while also increasing strength with no additional weight penalty.

So-called spread tow fabrics have seen increasing use over the past decade. These use thin tapes of carbon fabric, rather than yarns, to create a weave with a very low 'crimp' factor – the necessary bending of fibres as they cross over each other. It gives similar strength to cross plied unidirectional fibres, but with the drapability of woven materials. It also requires fewer material plies to achieve the same strength, thereby reducing weight.

Spread tows can also be produced with varied fibre types running in different directions, allowing for the mechanical properties of a finished part to be tailored to specific load paths.

Production processes

Traditionally, most carbon composite parts for racing, particularly sizeable parts such as monocoques, are produced using prepreg fabrics – sheets of fabric pre-impregnated with resin – that are cured in an autoclave. The various plies of fabric are cut and hand laid into a stack over a solid tooling, which is then enveloped in a vacuum bag and the air sucked out to 'debulk' the part, compacting the plies together. The part is then placed in an autoclave, where it is pressurised and heated to cure the resin.

Spread tows can also be produced with varied fibre types running in different directions, allowing for the mechanical properties of a finished part to be tailored to specific load paths

Control of this curing process is particularly important to the structural properties of the finished components, with a wide variety of factors having an influence. There are established curing cycles for prepreg materials, though even these sometimes need experimentation, depending on the make up of plies in the laminate stack. There are also various methods available to monitor curing in real time, for example, via dielectric sensors, which measure the change in resistance through a part as it cures.

With the migration of carbon composites from very high-end projects to the wider, more accessible market, both within motorsport and high-performance automotive, alternatives to the autoclave process are becoming more commonplace, with a focus on cost and production time.

A commonly used alternative to traditional composite fabrication methods is resin transfer moulding (RTM), also referred to as liquid moulding. RTM is a closed-mould

Digital Lighthouse / Red Bull Content Pool

The process of cutting out the individual plies is normally completed by automated means, but the lay-up and the various finishing processes are still manual tasks, carried out by skilled operators

A carbon composite production area looks less like a workshop and more like a cross between a laboratory and a drawing office, with machines constantly whirring and staff in pristine lab coats

The traditional carbon fibre production process used in racecar construction involves the use of prepreg fabrics, which are laid into a solid mould and then debulked (enveloped in a vacuum bag and the air sucked out), prior to curing in an autoclave

process that utilises a matched, two-part mould, typically made from metal or high-performance composite materials. Dry fibre material, often in the form of preforms, are positioned within the mould cavity, which is then sealed. Resin and hardener are accurately measured and combined and the mixed solution injected into the mould under pressure through strategically placed inlet ports, oriented to direct resin flow along predetermined paths to ensure uniform 'wet-out' of the fibres.

To achieve complete and rapid impregnation, particularly in thick or complex laminates, RTM formulations generally employ low-viscosity resins. In some cases, both the mould and resin are pre-heated to further enhance flow characteristics and reduce cycle time.

RTM can produce high quality, near net shape components without the need for autoclave consolidation. However, for applications involving elevated service temperatures, post-curing of the part after de-moulding is often required to achieve the desired thermal and mechanical performance.

Resin transfer moulding (RTM) can produce high quality, near net shape components without the need for autoclave consolidation

As well as the energy usage, the size limitations of autoclaves makes out-of-clave curing processes an attractive proposition for manufacturers looking to make large composite components

A notable variant of this technique is Light RTM, which integrates low-pressure resin injection with vacuum assistance. This approach allows the use of less robust tooling, such as lightweight composite or flexible membrane counter-moulds, making it an attractive option for lower cost or mid-volume production runs that need to maintain dimensional accuracy and surface finish.

Tooling time

In the area of tooling for composite part production, there have been numerous recent developments to both increase the complexity of parts and reduce cost and production time. For example, though the bulk of carbon fibre lay-up in motorsport is still done by hand, there are automated systems available that show fabricators the exact positioning and location of individual plies, projected over the tool.

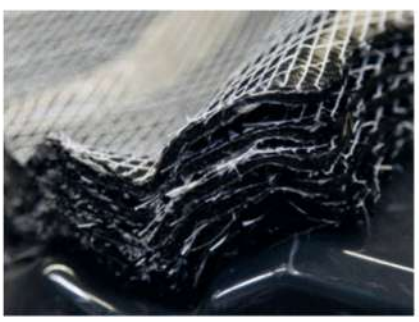
Looking towards low to mid-volume production levels, automated ply placement is becoming more widely used in aerospace applications. Previously, this approach was only really viable for use with tapes of material, limiting its usefulness, but new developments using robot arms and complex imaging systems can now accommodate the gamut of composite material forms.

In the hypercar space, McLaren Automotive recently unveiled its ART (Automated Rapid Tape) system, which automatically places prepreg tapes to

Automated patch placement is one of the recently developed techniques for producing carbon fibre composite tanks

[Light RTM] is an attractive option for lower cost or mid-volume production runs that need to maintain dimensional accuracy and surface finish

The manufacture of carbon fibre tows is an energy intensive and expensive process. As a result, there are considerable efforts being made to reduce the energy consumption and to improve efficiency and sustainability



It's a wind up

Traditionally, filament winding of composites has relied on what is known as a wet filament process, where the carbon fibre filaments are passed through a bath of resin before being wound onto a mandrel to create the form of a cylinder. Popular uses are for storage tanks, driveshafts and pressure vessels.

This approach has its limitations, though, not least the need for very tight process control to ensure consistent material properties. Consequently, alternatives are starting to see more widespread use, notably the use of towpreg material and robot placement of thermoplastic materials.

Looking at towpreg first, it offers several advantages over wet winding. Firstly, the steps of impregnation and winding are separated. The carbon tows are impregnated and wound onto a bobbin, creating a spool of material similar to prepreg materials used for other composite lay-up techniques. This material is then wound around a mandrel in the same way as a wet lay-up, but the properties of the towpreg permit faster winding speeds and a tighter winding pitch, reducing the amount of material used and cutting both cost and weight.

The disadvantage of towpreg is that, compared to wet winding, the materials are still relatively expensive and there is also less choice in terms of resin and fibres available.

Another interesting recent development is the use of thermoplastics, rather than thermosetting materials (which most epoxy resins are), which are placed on a mandrel using a robot arm and melted in place. There are several advantages to this process, notably no secondary curing process is required. Production can also be started and stopped at any time, something that is not possible with either traditional wet winding or towpreg.

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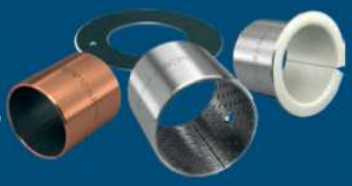

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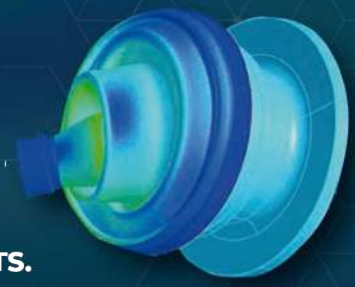

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Efforts are also underway to produce bio-based thermoset resins, moving the technology further away from a reliance on hydrocarbon-derived products

Carbon fibre composites formed using bio-based epoxy as part of a research programme for the European Space Agency

produce composite components at a rate compatible with car production, while also allowing for the orientation and placement of the tapes to be constantly varied to optimise the stiffness of parts as required.

There have also been advances in the tooling patterns themselves. US-based Smart Tooling has developed tools made from polymers that are rigid at room and initial cure temperature, yet become flexible at elevated post-cure temperatures. This allows them to be extracted from inside the part after production and then re-used.

Sustainability

Reflecting sentiment in both the automotive industry and wider society, sustainability is a hot topic in motorsport these days, and composites are one area where considerable work is underway to reduce the environmental impact of the technology.

Most readers will be aware of the bio-fibre-based composites produced by Swiss company Bcomp, which have seen extensive use in motorsport applications and have been covered in detail previously in *Racecar Engineering*. However, there are many other efforts going on to improve the credentials of composites. Notably, Mercedes, in partnership with F1 team sponsor, Ineos, and several other partners (including Toray), commenced a project in 2025 to investigate the qualification and use of sustainable composite fibres and resin systems in F1.

Beyond natural fibre reinforcement, recycling of carbon fibres and the use of bio-based precursors and resin systems are all at varying stages of development and commercialisation. One example is the use of lignin fibres as a precursor to produce PAN, while other projects are looking to commercialise plant and food waste products to produce bio-based acrylonitrile precursors.

Similar efforts are also underway to produce bio-based thermoset resins, moving the technology further away from a reliance on hydrocarbon-derived products.

Carbon fibre composites are unlikely to be usurped as the material of choice for racecar construction any time soon. Their combination of strength, stiffness and light weight remain, for the time being at least, unbeatable. And with ongoing materials development, combined with ever more advanced simulation and design tools, additive manufacturing techniques and production methods, their performance and useability is only set to increase, along with a corresponding reduction in their environmental impact.

Processes using bio-based precursors and resins are currently being investigated and developed for commercialisation

Resin developments

The type of resin used for carbon fibre composite components is dictated by the required mechanical properties of the finished part. Different resin system will have their own specific curing conditions.

Resins can be broken down into thermoplastic and thermosetting varieties, with the latter being the most widely used in motorsport. Within this subset one finds polyesters, vinylesters and epoxys. Each has its own benefits and disadvantages. Polyester-based resins are relatively low cost, while vinylesters have good toughness and chemical resistance. However, the most commonly found resin systems in prepreg materials are epoxies. These resins will often also contain additives to modify their performance for a particular application, be that strength, temperature resistance, conductivity or surface finish. For example, the incorporation of carbon nanotubes into resins has been shown to improve both strength and stiffness, as well as electrical and thermal conductivity.

High-temperature resins that can be handled in a similar fashion to low-temperature varieties have also been developed. Heat resistance is a key concern with composite parts. Although the carbon fibres are very tough, if the glass transition temperature of the resin matrix is reached, they start to lose structural integrity. Thermal barrier coatings can be used to protect composites, and can often be seen on areas such as the inside surfaces of engine covers, though they are only effective up to a point.

Where coatings are insufficient to provide the required protection, high-temperature resins are needed. For temperatures up to around 430degC, cyanate ester-based resins used to be the only viable option, but recent developments by material suppliers such as Toray have resulted in improved temperature resistant epoxies, good to nearly 200degC.

For extreme high temperature applications, bismaleimide (BMI) and polyimide resins are available. The latest resins are considerably tougher than previous solutions, which sometimes sacrificed durability for heat resistance.

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Fluid dynamic

From medical and military applications comes the technology required to keep drivers cool in extreme temperature environments

By BOZI TATAREVIC

Projects to improve driver safety in Formula 1 are typically the result of internal development, but the latest testing to reduce driver fatigue in hot climates comes from compact cooling devices, which first found widespread use in NASCAR.

For example, Chillout Motorsports offers a wide range of systems that are deployed in a variety of racing series, ranging from grass roots categories to top-level sportscar and stock car racing, and now the company's components are finding their way into F1.

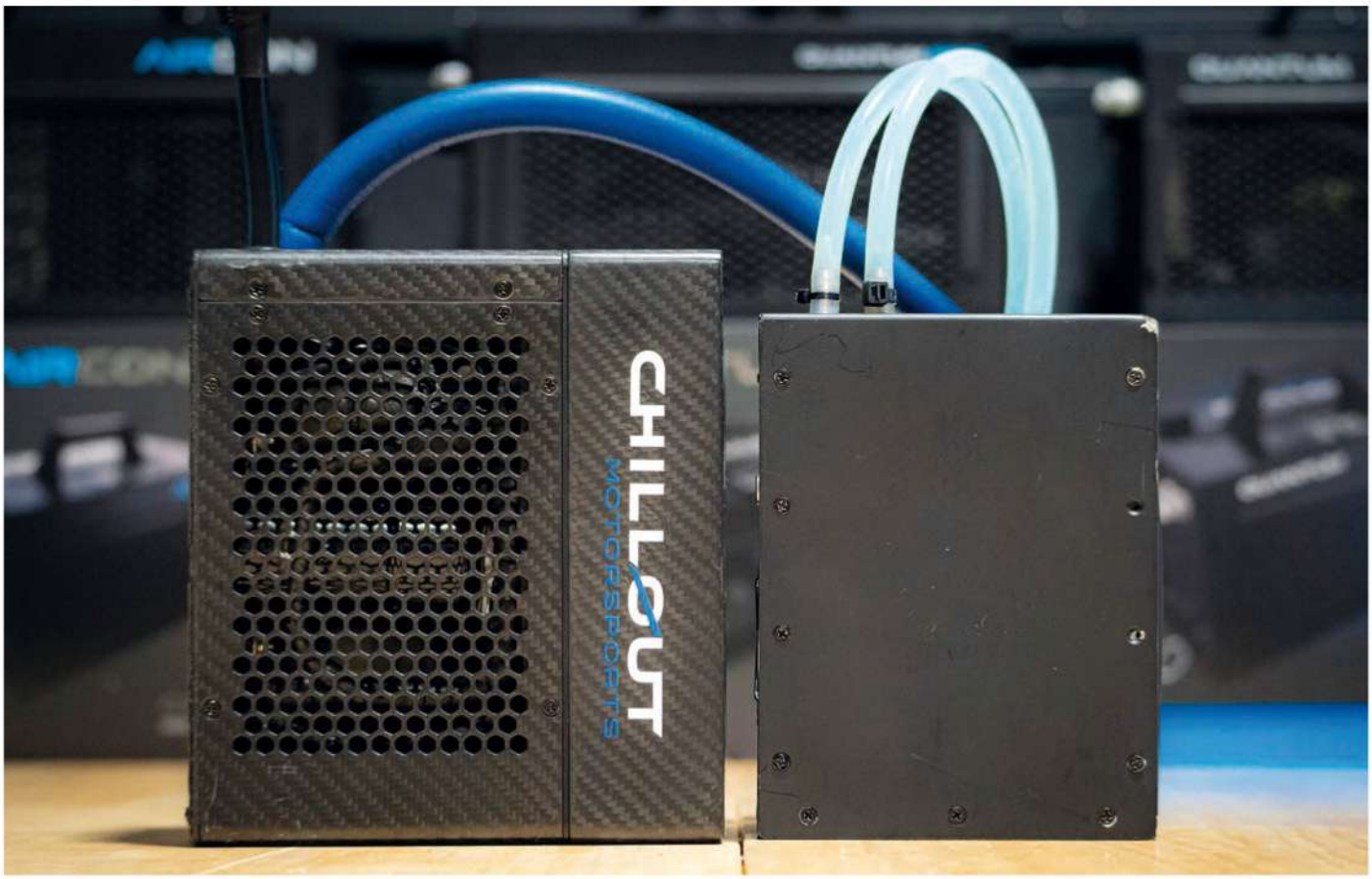
Driver cooling systems might be one of the few examples of racing technology working its way up the ladder, rather than trickling down. Ice-based cooling vests first saw use in medical settings, and were eventually adopted by amateur racers looking to bring down body temperature while wearing fire suits. Over time, these systems made their way towards professional racing series, but didn't become a regular sight in the NASCAR paddock until ice-less systems entered the market.

Medical history

Ice-based driver cooling systems were tested, and used, by some NASCAR drivers but, due to the sensitivities of placing weight on the right side of a stock car, most teams didn't want to make the compromise required to use them in the early days. Rini Technologies was one of the first companies to break into NASCAR at scale when it released a compact, ice-less system that was based on technology it had previously developed for military use.

Rini Technologies was established in the early 2000s, and has developed a variety of heating and cooling technologies for military personnel and equipment. For example, Rini developed a portable, battery-powered cooling system called the Personal Cooling System (PCS), aimed at helping provide heat stress relief for those that have to use chemical, biohazard and radiation protection (CBRN) suits. As this system weighed only 1.8kg, it formed the basis of the company's racing product, called the PCS-Auto.

Management of a driver's temperature is critical before, during and after a race. Technologies are being developed to meet all the safety requirements, while also being comfortable to wear



Chillout Motorsports driver cooling systems require no ice and use micro rotary compressors to chill the fluid flowing through them

Driver cooling systems might be one of the few examples of racing technology working its way up the ladder, rather than trickling down

The product was introduced after Hendrick Motorsports' crew chief, Chad Knaus, contacted Rini looking for a product to help prevent heatstroke in his driver.

The PCS-Auto used the same compact mini refrigeration unit as the PCS when it was released in early 2015, but offered the option of being directly wired to the 12V electrical system of a racecar. The system's compact size and low weight led to it being quickly adopted by many NASCAR competitors, and from there to make its way to IndyCar when the Aeroscreen was introduced (the design of which required additional driver cooling aids). The Rini Technologies PCS-Auto is the only unit currently approved for installation in the 2025 IndyCar rule book.

Market expansion

A new name entered the marketplace in 2019 when Chillout Motorsports launched its Quantum cooler. This required no ice and featured a 24V micro rotary compressor that chilled the liquid flowing through the cooler. Weighing in at around 5kg, it was rated for a draw of 19-22A.

Much like its predecessors, it found immediate popularity in amateur racing circles, but the unit's size and weight meant it wasn't likely to see significant use in top-level championships, where every gramme in the car is accounted for.

However, when more and more teams started adopting compact cooling systems, Chillout Motorsports set out to develop its own system that would work in weight-sensitive environments like NASCAR and in open-wheel series where space is also a consideration. A combination of these two factors was key to the company's systems recently ending up in F1 cars

Most NASCAR teams that use a system from Chillout Motorsports employ the Cypher series of micro cooler, which weighs

Exploded view of the components of a Chillout Motorsports Cypher Pro cooler. While being compact and weighing just 2.5kg, that's still too much to have in one place on an F1 car

in at 2.5kg and less than 8 x 4 x 7in in dimensions, allowing for the system to be mounted close to the driver's seat for optimal weight balance.

F1 application

The technology from the Cypher Pro series coolers forms the basis of the systems Chillout Motorsports has now started testing in F1. However, since space is even more limited in that application, some of the component parts have had to be split from the main cooler. We spoke to Chillout Motorsports' founder, Charles Kline, to find out more about the F1 driver cooling system.

'For now, we're developing bespoke systems for each team,' notes Kline, 'but only because we're working with a racecar where there's no room for anything, and trying to make a system that didn't exist fit into it.'

While the Cypher Pro cooler provided a good baseline for the F1 product, it was simply too large to fit as a single unit, which led to the development of split systems that separate some of the components.

'Right now, we're doing bespoke systems to work with the current chassis but, for 2026, the teams will know from testing, and from our developments, how much space they need to allocate for a modular system,' adds Kline.

'Sometimes the system will be mandated days in advance, based on weather forecasts, other times at the last minute, if the track temperature is exceeding what was expected'

Charles Kline, founder of Chillout Motorsports

The bespoke systems, which spread the weight of the components across multiple areas of the car, are a great first step when it comes to testing, but aren't a quick, or easy, install due to the fact the refrigerant that flows through them can only be charged once all of the pieces are connected.

'The systems are kind of broken into pieces to fit, so we might have half the system in the sidepod and half in front of the pedal box. It works, but just doesn't make sense, especially because sometimes the system will be mandated days in advance, based on weather forecasts, other times at the last minute, if the track temperature is exceeding what was expected. We need to be able to put the whole system onto a car in no more than two hours.'

The regular Cypher Pro system contains a rotary micro compressor, evaporator and condenser in its eight-inch long enclosure, but the F1 version sees the condenser unit mounted in the nose of the car, with refrigerant lines running to the remaining components mounted in an area like the sidepod. The system is still fairly compact at around 2kg, but current FIA rules require it to operate on independent battery power, which is why teams are allowed a total of 5kg for the driver cooling system.

The battery packs are 2.25kg lithium-ion units supplied by Chillout Motorsports, which are also an option with the company's off-the-shelf systems. A current complete F1 system, with the added battery packs, therefore weighs in at just under 5kg, though Kline is quick to point out that the target for 2026 is to supply complete systems that tip the scales at under 2kg.

A current complete F1 system, with the added battery packs, weighs in at just under 5kg, though Kline is quick to point out that the target for 2026 is to supply complete systems that weigh in at under 2kg

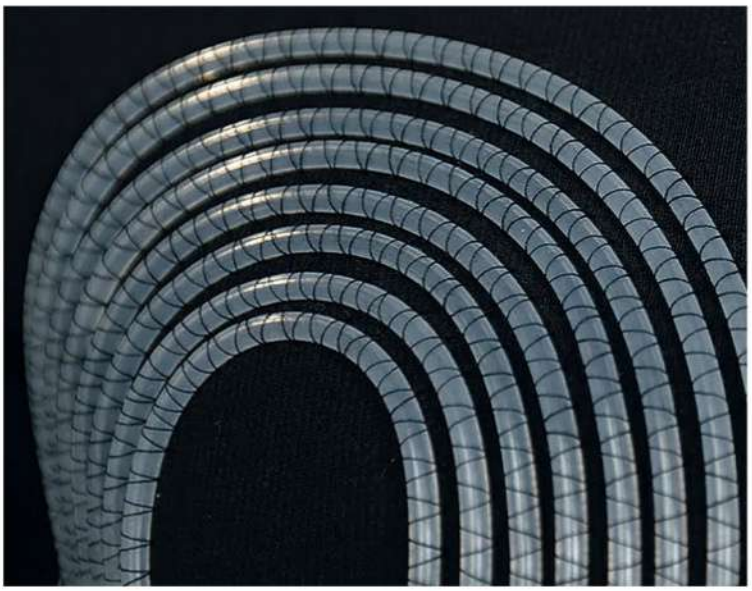
The coolers are connected to shirts with around 50m of tubing running up and down the front and back (Chillout Motorsports FIA / SFI-approved Pro Touring series shown). In some applications, a fluid reservoir will be sited on the vehicle, but in F1 the system is primed and bled with a removable bottle to save weight

Many of the cooling systems Chillout Motorsports supplies to existing race series feature a reservoir to hold the liquid and use a propylene glycol mixture that is pumped through the tubing of its shirts, but the systems being tested in F1 are so weight sensitive they do not have a reservoir at all. Like the systems deployed in NASCAR, they rely on a priming bottle, which is placed between the connector of the shirt and the pump to fill the shirt. Once the tubing in the shirt is bled free of air bubbles, the priming bottle is removed and the shirt is connected directly to the cooling system, so the water and propylene glycol mixture can circulate.

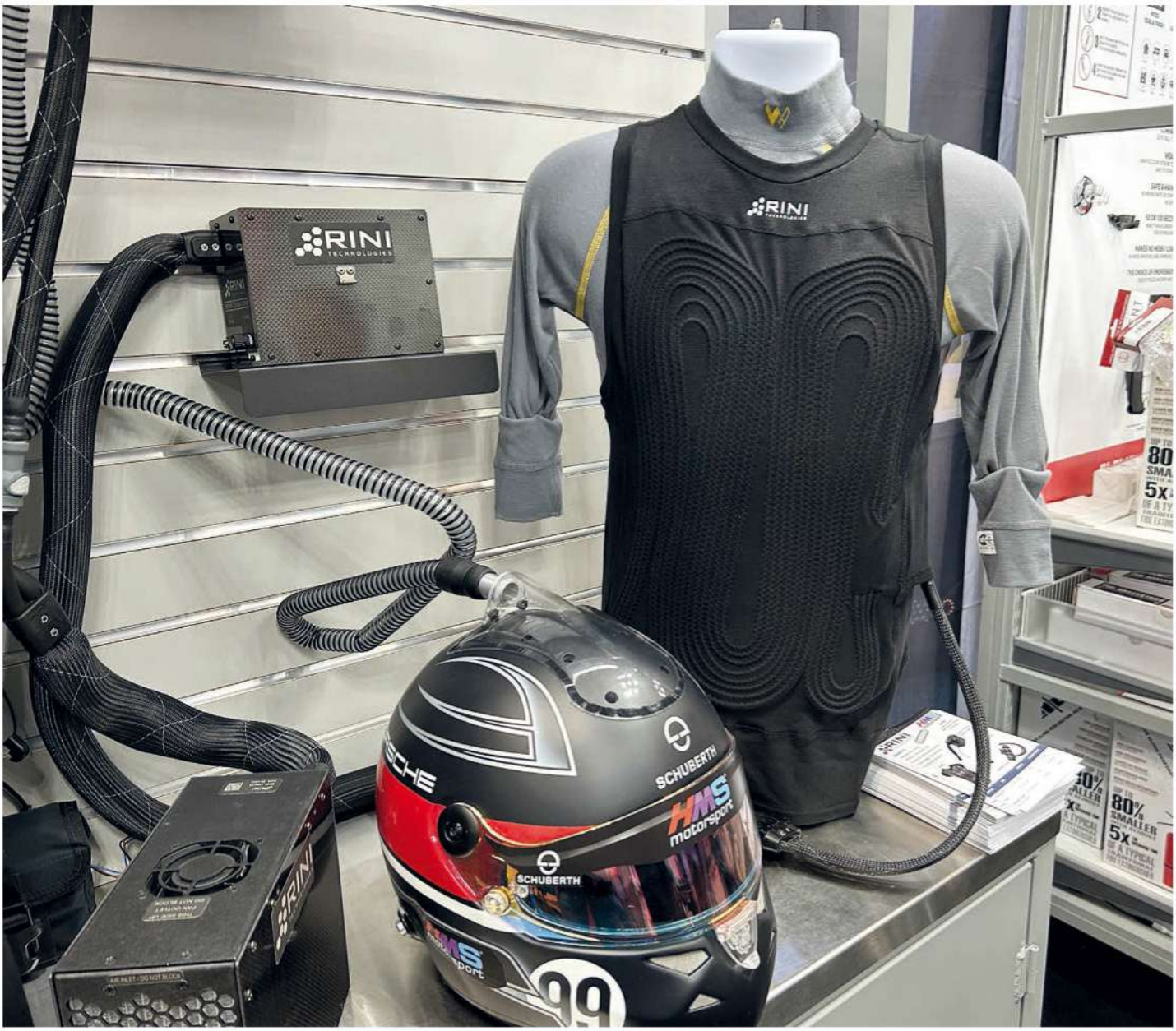
Body wash

As well as these substances, the cooling liquid Chillout Motorsports uses also features methylchloroisothiazolinone (MCI) and methylisothiazolinone (MI), preservatives often found in shampoo and body wash. In this context, they are employed to prevent microbial growth in the tubing and pump.

The 24V pump is rated for 150 hours' use, and Chillout Motorsports ships its Cypher Pro units with a spare so teams can service their own units without any down time.



A mixture of water and propylene glycol, with added preservatives, is pumped through the tubes



Rini Technologies is a player in the driver cooling market, and developed a shirt that complies with SFI standards for use in most US racing series. FIA standards, however, are more stringent

Perhaps surprisingly, the most complex part of these cooling systems isn't all the electronics and refrigeration equipment tucked away in the car, but the shirt the drivers wear, which contains around 50m of tubing to circulate the chilled liquid and help keep core body temperature under control.

Shirt approval

Companies like Chillout Motorsports and Rini Technologies have both developed shirts that comply with the SFI standard that is accepted by most racing series in the United States. However, F1 requires more stringent FIA approval, and to achieve that a multi-year development project was undertaken by Chillout Motorsports.

FIA regulations state that tubing on the outside of a shirt must meet the same fire resistance requirements as the shirt itself, or have a layer of the appropriately fire resistant material over it. Consequently, previous versions of FIA-approved cooling shirts basically sandwiched the tubing between two layers of fire resistant material, but that obviously adds weight, and can add to driver discomfort. Kline shared that developing better, more efficient shirts was the only way to get buy-in for his company's products with the drivers who would wear them.

FIA regulations state that tubing on the outside of a shirt must meet the same fire resistance requirements as the shirt itself, or have a layer of the appropriately fire resistant material over it

'Drivers didn't want to wear more material. They did have an FIA [-approved] shirt in the past, but it was a double layer so basically you had the tube sandwiched between two shirts sewn together. That's just crazy, it's like a sweater, so the drivers were like no way are we wearing that.'

In fact, drivers were so opposed to the idea of wearing cooling shirts that teams asked the likes of Chillout Motorsports to look for alternative technologies. Chilled seats were investigated but, due to the nature of the multiple layers of a fire suit, they were found to be not very effective at core temperature cooling, so the process cycled back to trying to sell the drivers on wearing a shirt with integral tubing.

Fortunately, long before the FIA came calling, Chillout Motorsports recognised that the only path to an FIA-approved shirt – at least, one drivers would be happy to wear – was to develop the tubing itself from a fire

resistant material. So, a few years ago, the company started testing new compounds for its tubing, with the aim of removing the need for an exterior layer entirely.

'For the last three years, we have been working on a compound for our tubes that is able to bend at both cold temperatures and high temperatures, maintain fire resistance for 15 seconds without melting or burning and be able to be glued together. It doesn't sound like that last bit would be too hard but, weirdly, these materials do not like sticking together, so the whole exercise was super challenging.

'That was the hardest part, but without it the systems are useless. No matter how small and how cool we make the system, it was irrelevant if we didn't give them a shirt they were happy to wear.'

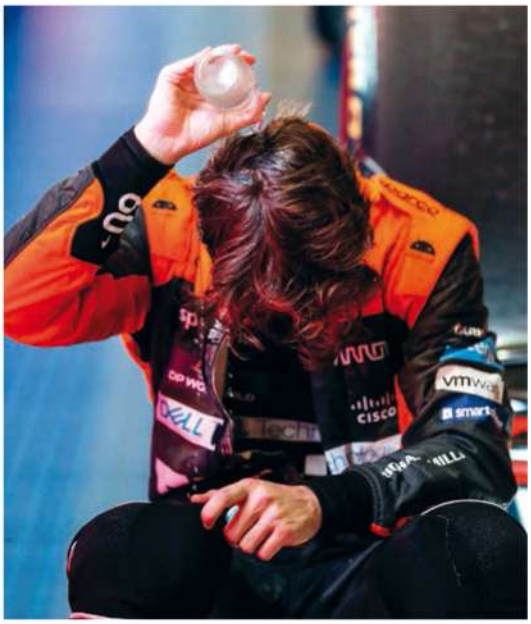
Quick release

In addition to the material properties, the FIA requirements also mandated updated connectors so the shirt (with driver attached) can be quickly released from the car, not only at the interface with the internal hose to the car but also where the sewn-in tubing on the shirt meets the external supply hose. Essentially, drivers need to have a quick release fitting in two different locations should they need to jump out quickly.

All of the development work has paid off as Chillout Motorsports recently received FIA approval for its Pro Touring line of shirts. These now carry FIA 8856-2018 specification, along with SFI specification 3.3, meaning they are legal to use in F1 and other FIA-sanctioned series worldwide.

Previous iterations of the cool shirt that are not FIA approved are not entirely redundant. They can be used in limited capacity in overseas series like SRO events, which allow drivers to wear them provided they place an FIA-approved shirt over the top. However, certain sanctioning bodies in the Middle East – an area of the world that sees some of the highest track temperatures – only allow the use of fully FIA-compliant shirts so, perversely, not many drivers there have been using cooling systems.

McLaren



Driver cooling has become a hot topic, with increased understanding of the effect of heat exhaustion on driver wellbeing and performance

Options are currently being tested that allow all of the components to be packaged in a single unit but, just as in NASCAR, [Chillout] is having to negotiate with F1 teams to get the necessary cooling air to the units

That said, Kline shares that over the winter Chillout Motorsports found a distributor in the Middle East, and that it received requests for hundreds of the new shirts in the run up to the 24 Hours of Dubai in January. Indeed, the distributor had to limit quantities individuals could buy in order to be able to supply as many customers as possible, due to Chillout's limited production capacity.

'Everybody wants five of these FIA shirts, and we can only build 10 or 12 a day,' notes Kline. 'It's just such a time-consuming process. We have 10 people on the project, but it takes all day to build one shirt. There's eight to 10 hours work in each one.'

While this is a new process, using new materials, Kline says Chillout has managed to keep costs contained, with only a marginal increase compared to its old SFI shirt, and coming in around $400 less than the previous FIA-approved shirt on the market.

Developing a custom compound for the tubing has also allowed Chillout Motorsports to increase the length of the tubing used. So, where the previous FIA-approved shirt had around 12m of tubing, a Pro Touring shirt packs 50m of pipe, with a corresponding improvement in its cooling capacity.

Airflow battle

The goal for Kline and Chillout Motorsports now is to develop a system for 2026 that is not only about half the weight, but which can be packaged in such a way that it is easy to install and remove from the cars when needed. Options are currently being tested that allow all of the components to be packaged in a single unit but, just as in NASCAR, the company is having to negotiate with F1 teams in order to get the necessary cooling air to the units.

The current iteration of its test unit pulls air in through a duct in the nose and then uses fans to push that air to the condenser, but teams are already looking at how to make the ductwork smaller to minimise airflow disruptions over the car.

Chillout has dealt with similar issues in NASCAR after investigating unit failures. For example, NASCAR teams have been known to place mesh screens in the ducts leading to the Cypher cooling units to improve overall airflow numbers, but at the expense of airflow to the coolers, leading to eventual failures. When NASCAR discovered these tweaks were being made to the systems, it implemented a mandate that required all driver cooling system diagrams be shared with the series and published in the parts database. In addition, NASCAR has recently made tweaks to the rulebook in an effort to minimise the games being played with fans around driver cooling, as seen in rule 14.12.6.B, which now reads as follows:

'A driver cooling assembly may consist of any combination of cooled air systems, non-cooled air systems, liquid cooled systems, carbon monoxide (CO) catalyst systems, liquid-based vest systems, associated electrical components, soft or hard ducting, NACA duct(s) and / or other system intakes. Assembly intakes may only include one or more of the following: windshield assembly driver cooling duct, cockpit open inlet(s), or quarter window NACA(s). Assembly exhausts must all be internal to and discharge only within the cockpit, and may only include one or more of the following: driver's helmet, driver's body, seat insert, leg and / or toe board area, ECU, or assembly heat exchangers. All driver cooling assembly fans must be electrically and mechanically configured to only be capable of moving air from assembly intake(s) towards exhaust(s). A driver cooling assembly exhaust may not be used as a driver cooling assembly intake.'

Future of driver cooling

Kline says he would like to see a mandate from the FIA that requires F1 teams to create a spot for the driver cooling units so that teams are required either to run a unit or a compensation weight in the same position. This, he argues, would encourage system usage and allow the company to standardise the units to reduce cost.

The goal is to package the driver cooling unit in such a way that all the components are close enough that additional refrigerant lines and / or extra fans are not required. Based on current testing, Kline foresees the likelihood of creating two or three variants of the system so F1 teams can choose their preferred version based on climate and aerodynamic performance requirements.

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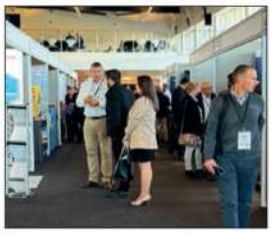

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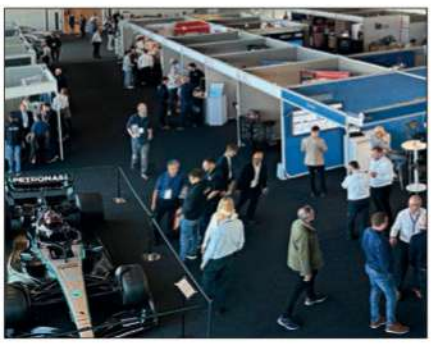

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Inverter logic

The Hypercar class is an underappreciated hotbed for MGU and inverter development. Ferrari's technical chief gives the lowdown

By ANDREW COTTON

Part of the cost saving was in the reduction of development opportunities… but that does not mean development has stood still

There are significant technical differences between LMH and LMDh that have to be overcome. Having won the first two races of the WEC this year, Ferrari is in the hot seat headed to Le Mans

When the FIA and the ACO were mapping out the Hypercar concept for the FIA World Endurance Championship (WEC), they looked at bringing down the cost of competition from the old LMP1 era. There, hybrid and car development ran out of control, with budgets so large that few manufacturers could even consider entering the competition.

The Hypercar class, specifically the LMH regulations within it, saw manufacturers build their cars from the ground up. It was designed to be around one tenth of the cost of competing in LMP1. In truth, that was an ambitious target, and budgets today are estimated to be around one third of the previous era. Still a significant saving.

Added to the mix was the LMDh rule set, which made its debut in the 2023 season after two years of LMH in action. LMDh was developed jointly between IMSA and the ACO. Adopting LMDh as a second type of car in the top class became a critical element in the evolution of the rules, especially around the hybrid system. LMH manufacturers were forced, by regulation, to run their MGU-K on the front axle, while LMDh had to use a standard Bosch system on the rear.

Under the skin

Part of the cost saving was in the reduction of development opportunities. Cars are homologated and cannot be changed without prior approval from the governing bodies. Within their lifespan there is only so much that can be done, but that does not mean development has stood still.

By regulation, the absolute maximum power of an LMH is limited to 500kW, although that figure can then be further adjusted by the Balance of Performance system, up to 520kW. This power can be delivered by the internal combustion engine to the rear wheels, or by a combination of ICE and electric power from the MGU.

To achieve smooth power delivery without exceeding the maximum power output, electronics control the amount of power delivered to the driving wheels. The aim of the game is to get as close to the torque curve as possible, without exceeding it at any point around the track, and to ensure the power delivery is as smooth as possible.

While this is controlled by electronics, the question is whether or not it is better to have a bespoke design of motor and inverter in an LMH car, or simply run the standard Bosch MGU-K found in every LMDh car.

Key to this discussion is that, while the hardware cannot be touched without a so-called 'joker' being played, the software can be developed throughout the car's lifetime. Which works better?

The power of six

Where the most common solution is a three-phase controlled electric motor, Ferrari is controlling it with six phases. The six-phase inverter is integrated into the ES pack rather than on the central spine to optimise packaging, efficiency and weight. 'Contrary to LMDh, the possibility to design the hardware as we like, or as we believe, is there for us,' says Ferrari's head of endurance racecars,

Le Mans Hypercars, by regulation, have to run an MGU-K on the front axle. In the Ferrari 499P this means the electric motor has to be geared down from 25,000rpm to the roughly 3000rpm maximum of the front wheels. This requires a more robust (heavier) set of gears than is needed to step down a rear-mounted motor to engine speed

Ferdinando Cannizzo. 'There is clear research in the material of the electric motor, on the power electronics of the inverters, and the way to match the electric motor with the inverter in the most efficient way is important.'

Due to the limit imposed on overall power, the motors and inverters are not designed for maximum performance. So there is nothing to be gained by increasing the output from the motors, other than to reach the permitted ceiling quicker.

'The more efficient the control, the better it is for the life of the inverter, since for the same power there is less heat generated which means lower temperature of power electronic components, and less demand on the cooling system,' explains Cannizzo. 'You get more precise conversion and this is allowed by the regulation, which does not constrain the way you do the electric motor, or the way you do the inverter, or the battery, so we can go deep on all this.'

Each manufacturer has the opportunity to tune its inverters to create the required electrical energy, and here's where differences can arise. 'You can understand how efficient the system needs to be,' says Cannizzo. 'The six-phase switching control allows really precise control, and at the same time it is very efficient, minimising the heat generated by the energy passing through the power electronic devices.'

Maximum speed

The LMH MGU has a very different requirement to function versus that of an LMDh. One key difference is the reduction gear. 'When you have an electric motor in the front, you need to calibrate the motor to the speed of the wheels,' explains Cannizzo. 'They are rotating at roughly 3000rpm at maximum speed, maybe more. When you are talking about putting one at the back, it runs at the speed of the engine, which is around three times more.' So, if an engine runs at 9000rpm and the maximum rotational speed of the motor is 25,000rpm, the step down is smaller than it is at the front wheels.

'In our case, we need to move from 25,000rpm to 3000rpm. It's a huge step down and the reduction gear is bigger and heavier,' Cannizzo continues. 'The [rear motor] is a little more difficult to control because it needs to follow the engine transient, while in the front it follows the wheels. So there are different problems, but they can apply torque with the ERS system and combine it with the engine in acceleration and braking. They also have only one axle [to worry about] and no limitation in applying the ERS power, so they can speed up from zero km/h, and remove turbo lag or lower engine response. They put the torque in immediately.

'You can see this difference in the different cars, depending on the displacement of the engine, and we are not able to do it [with a 3.0-litre V6]. There is a clear difference with LMH and LMDh, and the LMHs with a bigger engine are advantaged among LMH cars but disadvantaged compared to LMDh.

'The [6.5-litre V12] Aston Martin, for example, is a good choice with this regulation, but it wasn't with the previous regulation when we had no constraint on the usage of the system.'

Motor development

The motors for the 24 Hours of Le Mans-winning Ferrari 499P were developed from the start of the design process to take this issue into account through gearing, but development is ongoing: 'We keep working on it, but within the limit of the technical regulations,' confirms Cannizzo. 'There are changes, but within the homologation document. When we first developed the system, we took into consideration size, how much space we had for the electric motor, how much torque, what revolutions we would like to achieve and the space for the gears to make the optimum gear ratio for Le Mans and the other tracks. All this was taken into consideration.

'The six-phase switching control allows really precise control, and at the same time it is very efficient'

Ferdinando Cannizzo, head of endurance racecars at Ferrari

'If you do an LMDh, it maybe fits the average but maybe not your car. I don't think Bosch can go those last miles of development.'

As it develops the 499Ps hybrid system, Ferrari's endurance squad is feeding its knowledge into other areas of the company, particularly the development of road cars. The experience gained in endurance racing and the know-how required in competition are essential aspects of the technology transfer that creates a link between race cars and road cars, and vice-versa, Ferrari tells us. It's a link that is often touted, but their development of hybrid motors is clearly important to the overall activities.

When it comes to developing hybrid electric motors and inverters, endurance racing is where some of the brightest minds are currently plying their trade.

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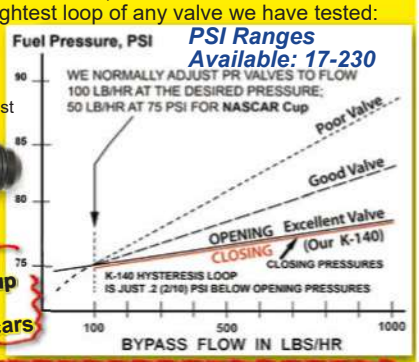

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Overdue update

The hand calculation reference book, 2025 edition

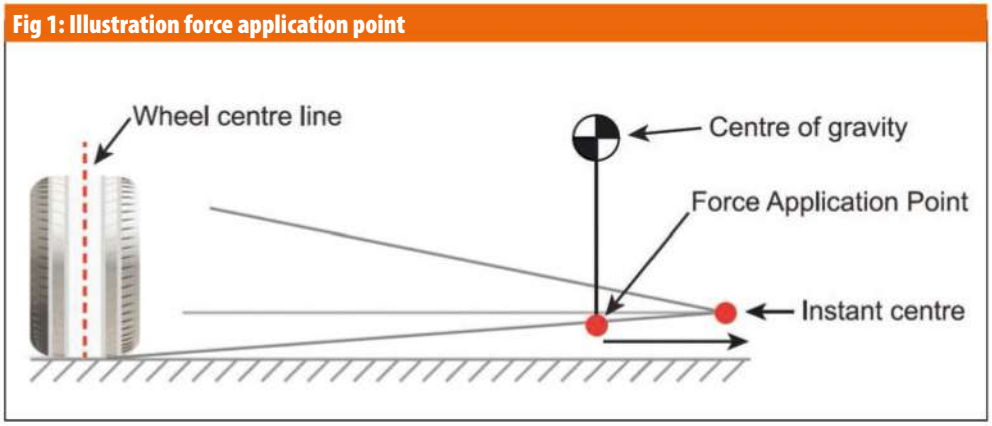
By DANNY NOWLAN

Different racecars exhibit distinctive characteristics in roll and, while many turn to computers to help find the optimal solution, hand calculations are critical to ensuring you stay on the right path

Recently, as I was doing the rounds of the FIA Formula 2 and 3 paddock at the Australian Grand Prix, one of the team managers recognised me and said hello. We got chatting and, in the course of the conversation, he mentioned a 2024 article called the 10 equations everyone should know. I said that sounds really good, can you send it to me? He explained that he didn't have it, but motioned his technical director over who showed it to me. It was only my hand calc' reference book article from 2014! He went on to say they make all their junior engineers read it, which just goes to show how foundational the techniques mentioned continue to be.

The purpose of this month's article, then, is to give you an updated instalment of that 2014 article, which I think is long overdue. My original article focused on load transfer, how to run the numbers on front lateral load transfer and how to compute tyre loads and damping ratios.

Fig 1: Illustration force application point



A revised version of that article I produced in 2020 reviewed some of this, and also added in how to calculate roll, converting roll bars specified in Nm/deg to N/mm and gave a really good load transfer example that provides a great tool for use in simulation validation. For this latest instalment, I'll also be discussing jacking forces and what to do with tyre data.

To kick things off, let's talk about crunching the numbers of weight transfer through the sprung mass vs jacking forces. To get our heads around what we're trying to do here, we need to understand what is meant by force-based roll and pitch centres and, in particular, the force application point. To refresh everyone's memory, this is illustrated in **figure 1**.

The real money shot here is figuring out the load transfer, as it happens in a most revealing way

The important thing to note here is that the force application point tells us the moment that is applied to the sprung mass and the load that is directly applied to the chassis. This applies to both lateral and longitudinal members. The detailed proofs I cover in chapter three of my book, *The Dynamics of the Race Car*, but **equation 1** shows what you are looking at.

$$M_{cg} = F \cdot \left(h_{cg} - h_{FAP}\right)$$
$$J_F = \frac{F \cdot h_{FAP}}{t} \quad (1)$$

Where,

M_{cg} = Moment the force application point applies about the c of g
h_{cg} = Height of the c of g of the car
h_{FAP} = Height of the force application point
F = Longitudinal / lateral force applied through the force application point
t = Length of the contact patch to the force application point
J_F = Jacking force

Here's where things become interesting. The jacking force is what puts the load transfer straight into the tyre. That load transfer is instant. However, the jacking force is what lifts up the sprung mass. Hence why it's called jacking force. The load transfer through the sprung mass, M_{cg}, has to be reacted by the sprung mass and is inherently slower. That said, you can use it to your advantage in high downforce cars.

Now let's put some numbers to this. To do so, we'll consider a braking force of 10,000N for a single-seater car. The other relevant numbers are shown in **table 1**.

Table 1: Examples for jacking force calculations

Parameter	Value
Braking force (*F*)	10,000N
C of g height	0.3m
Force application point	0.1m
a	1.6m
b	1.0m

Running these numbers through **equation 1**, we see

$$M_{cg} = F \cdot \left(h_{cg} - h_{FAP}\right)$$
$$= 10000 \cdot (0.3 - 0.1)$$
$$= 2000Nm$$
$$J_F = \frac{F \cdot h_{FAP}}{t}$$
$$= \frac{10000 \cdot 0.1}{1.6}$$
$$= 625N$$

At this point, you might be thinking this is all well and good, but so what?

Table 2: Plot of normalised ChassisSim slip angle derivatives

Slip angle (deg)	Slip angle (rad)	Normalised value	δC/dα
0	0	0	14.323
1	0.0175	0.214	13.925
2	0.0349	0.44	12.731
3	0.0524	0.604	10.742
4	0.0698	0.761	7.9567
5	0.0872	0.889	4.375
6	0.1047	1	0

First things first. The geometry is applying 625N, or 63.8kgf, of force straight into the front tyre. We'll come back to this in a moment, because the real money shot here is figuring out the load transfer, as it happens in a most revealing way. So, let's presume the car's weight is 700kg, and the distance of the rear axle from the c of g (b) is 1m. To work out what the forces are at the front and rear, a force and moment balance shows that depicted by **equation 2**.

$$700 \cdot 9.8 - J_F = F_{FNT} + F_{REAR}$$
$$F_{FNT} + F_{REAR} = 6235N \quad (2)$$
$$\Sigma M_{CG} = F_{FNT} \cdot a - M_{FAP\_CG} - F_{REAR} \cdot b = 0$$
$$M_{FAP\_CG} = F_{FNT} \cdot a - F_{REAR} \cdot b$$

That gives us two equations and two variables. Solving for this we have **equation 3**.

$$F_{FNY} = 3167.3N$$
$$F_{REAR} = 3067.7N \quad (3)$$

If you're now thinking something's not right, this doesn't add up to the total vehicle weight and load of 700kg, you are correct. That's because we've missed the jacking force at the front. Corrected for that, we have that shown in **equation 4**.

$$F_{FNY} = 3167.3N + J_F$$
$$= 3167.3 + 625 \quad (4)$$
$$= 3792.31N$$
$$F_{REAR} = 3067.7N$$

Now comes the *coup de grâce*. Going back to the 2014 version of this article, pull out the load transfer equations using the static load. This time our total wheelbase is a + b = 2.6m, and weight distribution, *wdf*, is 38.46 per cent. Running the numbers, we have **equation 5**.

$$F_{FNY} = wdf \cdot m_t \cdot g + \frac{F_x \cdot h_{cg}}{wb}$$
$$= 0.3846 \cdot 700 \cdot 9.8 + \frac{10000 \cdot h_{cg}}{wb}$$
$$= 3792.31N$$
$$F_{REAR} = (1 - wdf) \cdot m_t \cdot g - \frac{F_x \cdot h_{cg}}{wb} \quad (5)$$
$$= 0.615 \cdot 700 \cdot 9.8 - \frac{10000 \cdot h_{cg}}{wb}$$
$$= 3067.7N$$

The results of **equations 4** and **5** are identical, but what we have just illustrated is the mechanism of what affects load transfer. So, the sprung mass loads are dictated by the force balance between the car's mass and load minus the jacking force and the moment balance. The jacking force applied to the tyre then tidies up the weight, which ties in nicely with what we saw in 2014.

Force impact

Where things get really interesting, though, is the impact of the force application point, particularly longitudinally. We can use the force application point to dictate the moment the sprung mass has to deal with. This is particularly useful when dealing with cars that are highly pitch sensitive. Be careful though, as you can overdo it, and that is usually when the car gets spooky. Longitudinally speaking, this is a slam dunk. Laterally, there are some compatibility issues that muddy the waters, but that is an article I'll save for another time.

The next item for discussion is calculating tyre force gradients, and this really helps give us a first cut of understanding car stability. To set up this discussion, let's take a look at the normalised tyre force gradients from the ChassisSim tyre model, shown in **table 2**.

All we are doing to calculate these slopes is to take the normalised values and plot the gradients. Now that we have these figures, how do we use them? To illustrate this, we are going to do a simple stability index calculation, using the sample numbers shown in **table 3**.

Table 3: Typical values for stability index based around an F3 car

Item	Description	Value
Fm_1+Fm_2	Sum of traction circle radius for the front	5000N
Fm_3+Fm_4	Sum of traction circle radius for the rear	7000N
a	Distance of front axle to the c of g	1.6m
b	Distance of rear axle to the c of g	1.1m
wb	Wheelbase	2.7m

Even FIA Formula 3 engineers are sometimes in need of a refresher, although an experienced hand on the tiller helps to guide them in the right direction

Let's say the front slip angle is five degrees and the rear slip angle is four degrees. Using the derivatives from **table 2**, the stability index is shown by **equation 6**.

$$
\begin{aligned}
C_f &= \left.\frac{\partial C_f}{\partial \alpha_f}\right|_{\alpha=\alpha_f} \cdot (F_{m1} + F_{m2}) = 4.375 \times 5000 = 21875 \\
C_r &= \left.\frac{\partial C_r}{\partial \alpha_r}\right|_{\alpha=\alpha_r} \cdot (F_{m3} + F_{m4}) = 7.9567 \times 7000 = 55760 \\
C_T &= C_f + C_r = 77634 \\
stbi &= SM / wb \approx \frac{a \cdot C_f - b \cdot C_r}{C_T \cdot wb} \\
&= \frac{1.6 \times 21875 - 1.1 \times 55760}{77634 \times 2.7} \\
&= -0.125
\end{aligned}
\qquad (6)
$$

That is a really good back of the beer coaster calculation you can use to determine the stability index. Let me be very clear here that the *Fm1 + Fm2* and *Fm3 + Fm4* items are the sum of the traction circle radius (D) term of the tyre.

Now, here's a little project for those of you that can dig up my 2014 edition of this. You can now combine the tyre load equations I presented and, if you have a traction circle radius vs load characteristic of your tyre, use that to construct a simple Excel spreadsheet to get a handle on what your car is doing stability-wise. Combine that with my article on tyre modelling from nothing and, to quote my late mother, you'll certainly be off to the races.

For completeness here, the full equation for the stability index is given in **equation 7**.

$$
\begin{aligned}
C_f &= \left.\frac{\partial C_f}{\partial \alpha_f}\right|_{\alpha=\alpha_f} \cdot (F_{m1} + F_{m2}) \\
C_r &= \left.\frac{\partial C_r}{\partial \alpha_r}\right|_{\alpha=\alpha_r} \cdot (F_{m3} + F_{m4}) \\
C_T &= C_f + C_r \\
stbi &\approx \frac{a \cdot C_f - b \cdot C_r}{C_T \cdot wb} - \frac{a^2 \cdot C_f + b^2 \cdot C_r}{V_x \cdot C_T \cdot wb}
\end{aligned}
\qquad (7)
$$

You'll notice the extra term here is yaw damping. My suggestion is start simple on **equation 6** and, once you are comfortable with that, move on to **equation 7**.

For this edition, I'm also going to throw in a little bonus. For those of you doing force balances, **equation 8** is a great rule of thumb.

$$
\alpha_F = \frac{b \cdot (Fm(L_3) + Fm(L_4))}{a \cdot (Fm(L_1) + Fm(L_2))} \cdot \alpha_R \qquad (8)
$$

Where,

a = Moment arm of front axle to c of g (m)
b = Moment arm of rear axle to c of g
a_f = Front slip angle
a_r = Rear slip angle

The trick when you are doing this is to set the rear slip angle to, say, five degrees. It's not perfect, but it's a great addition to any set-up sheet you create that will help you see what you are actually doing.

Damper behaviour

Another often overlooked hand calc' is working out damping curves from first principles. In my articles on the damper workbook, and in the bootcamps I give, I talk a lot about damping ratios. I focus on this because it's the crux of what drives damper behaviour. What we in the vehicle dynamics / damper community have done a poor job of is showing how this translates to a force vs damper curve. There's no excuse for that as the equation is straightforward. For a simple dual rate damper model with velocities less than the bypass, the forces will look like that shown by **equation 9**.

$$
\begin{aligned}
F_{DAMP\_BUMP} &= C_{LSB} \cdot v_{bump} \\
F_{DAMP\_BUMP} &= C_{LSR} \cdot v_{rebound}
\end{aligned}
\qquad (9)
$$

Go through the bypass and **equation 10** is the animal you're dealing with.

$$
\begin{aligned}
F_{DAMP\_BUMP} &= C_{LSB} \cdot v_{bump\_bypass} + C_{HSB} \cdot (v_{bump} - v_{bump\_bypass}) \\
F_{DAMP\_BUMP} &= C_{LSR} \cdot v_{rebound\_bypass} + C_{HSR} \cdot (v_{rebound} - v_{rebound\_bypass})
\end{aligned}
\qquad (10)
$$

Where,

F_{DAMP_BUMP} = Damping force in bump (N)
$F_{DAMP\_REBOUND}$ = Damping force in rebound (N)
C_{LSB} = Low speed bump slope (N/m/s)
C_{HSB} = High speed bump slope (N/m/s)
C_{LSR} = Low speed rebound slope (N/m/s)
C_{HSR} = High speed rebound slope (N/m/s)
v_{bump_bypass} = Bypass velocity in bump (m/s)
$v_{rebound\_bypass}$ = Bypass velocity in rebound (m/s)
v_{bump} = Velocity in bump (m/s)
$v_{rebound}$ = Velocity in rebound (m/s)

The only thing to be mindful of here is that bump forces are positive and rebound forces are negative. It is also imperative you work in strict SI units otherwise you'll be on a hiding to nothing. The ChassisSim front end makes this easier for you, but it's readily implementable in Excel.

The beauty of this approach is it lends itself to quick turnaround simulations when you are doing dampers. I, and many other members of the ChassisSim community, have leaned on this very hard and it's got us out of quite a few tough situations, so I can confirm from first-hand experience that this is a very handy tool to have in your toolbox.

In closing, we have covered quite a bit in this, the 2025 edition of the hand calc' reference book. We've discussed what drives suspension geometry, tying in tyre models to driveability, and shown a great reference tool for doing damper work. This all adds to the good work that has already been done in the 2014 and 2020 editions of this article. It's now over to you, dear reader, to put it into practice to improve your racecar.

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GT rising

GT3 continues to grow in popularity but, in SRO international races, interest has gone stratospheric.* Racecar *talks to Stéphane Ratel to find out why

By ANDREW COTTON

The world of GT racing has faced challenges in the past, with escalating costs and manufacturer involvement driving away the core customer base, yet the category is currently enjoying an incredible purple patch. GT3 is the premier category in many national championships, as well as the international GT World Challenge events and the DTM. It is a sub-category in the World Endurance Championship and other Le Mans Series races around the world and, consequently, could be counted as the most successful rule set ever created for racing.

There are thousands of GT3 cars racing around the world and manufacturers have flocked to it. The GT World Challenge alone boasts 10 competing manufacturers, and there are more in other series.

However, the architect of GT racing, Stéphane Ratel, has long prophesised the end of the class, citing higher purchase costs for the car, increased manufacturer interest in factory racing and new regulations by the FIA, which have led to a prototype-style design, as contributing factors. As numbers continue to grow on an international level, the signs are indeed there that all is not perfect. Numbers have dropped markedly at national level, even in events organised by the Stéphane Ratel Organisation (SRO).

Standard bearer

At the opening round of the GT World Challenge Europe, at Paul Ricard in France, a record number of 59 cars took the start of the race, and the endurance series continues to be the standard bearer for GT3 racing. 'It is the only series in the world that has had an average of over 50 cars for more than 15 years,' says Ratel. 'It is good, and we must be doing something right.'

> **'[GT World Challenge Europe] is the only series in the world that has had an average of over 50 cars for more than 15 years'**
>
> *Stéphane Ratel*

So, why the pessimism, and does that still resonate with the Frenchman? Ratel remains cautious that the class could still implode. 'It is a fact that every category in sportscars and elsewhere, when you have rising cost, it is followed by a fall, and it can be a sudden fall,' he warns. 'That is the experience I have seen with generations of GT1, and more recently with GTE, so there is a tendency to believe the same will happen.

'Maybe GT3 can sustain this cost because it has gone so global, and the world in the last 15 years has generated more wealth and a larger number of people that are able to sustain this rising cost. You certainly have more people involved than we had 20 years ago, and you have more wealth in the paddock, but that does not mean we are immune from a rapid fall.

All photographs: SRO / JEP

Stéphane Ratel (centre) with Lutz Leif Linden, FIA GT commission chairman (left) and Mercedes' head of customer racing, Stefan Wendl

Race start at Paul Ricard for the GT World Challenge Endurance event shows the strength of the category, with 10 manufacturers involved

'In 1997, I remember Ray Bellm coming to me as I was watching this amazing race, with 50 cars or something, and saying, "You are enjoying your grid?" I said yes, I was enjoying it. He then said, "It is a beautiful funeral procession. Half of it will be gone next year." And he was spot on; we went from 50 cars to 25. That is why I am considerate of cost. I remain a strong opponent to torque sensors, or anything that adds €200-300,000 to a season. It is a fact, that anything that raises costs is dangerous for the category.'

Balancing office

Torque sensors have already been introduced to FIA-run categories such as the World Endurance Championship, and the GT World Cup in Macau, and have been adopted by the IMSA Sportscar Championship. While the unit cost is not expensive, the running costs are, and teams have often complained that they're crippling.

To avoid torque sensors, and increase the depth of its performance balancing office, the SRO has incorporated a new BoP structure for the 2025 season. In the past, it relied almost solely upon the services of Claude Surmont, a race engineer of considerable repute. However, with so many championships, and now so many manufacturers competing in the series, it was time to relieve some of the pressure on him.

The first step was to close off differences between the DTM regulations and the SRO events, which allowed manufacturers to develop their cars under the DTM regulations and carry that benefit into the GT World Challenge. That made performance balancing more of a challenge than it should have been, so there is now a new homologation document that goes alongside that of the FIA.

New FIA rules allowed greater freedom in design, and Ferrari exploited that to the maximum, although it is far from the most expensive car on the grid. For 2025, a new, additional homologation document aims to close up the grid

To avoid torque sensors, and increase the depth of its performance balancing office, the SRO has incorporated a new BoP structure for the 2025 season

'In the homologation forms there were grey areas and, as the competition rose, and the budgets, some teams were able to optimise many areas, and could gain two tenths,' says Ratel. 'You can go from pole to 26th in two tenths of a second.

'Claude did a fantastic job with the DMSB to define the areas where teams were doing the optimisation, while remaining within the rules. So, we are showing that with this new homologation form, which is additional to the FIA form, but adding our own specification to close the gaps.'

Majority rule

The second stage was to open up the BoP process. Engineers look over the same race from the previous year, come up with a BoP that reflects what happened there, taking into account any car evolution, and then publish that on a open forum. The manufacturers then have a chance to respond, and any comments can be seen by the other manufacturers. The chance of that being a smooth process is slim, but Ratel is hoping it will improve the system.

The final part is to introduce a committee to analyse the data from the platform. Surmont receives help from two trusted engineers who will sit alongside him and agree by majority what should be done with the table based on the comments.

'On event, we have three people,' continues Ratel. 'Xavier Schene, who is president of the FIA Homologation Commission and technical director of the RACB, which is our ASN. He is very qualified, and we needed someone neutral with long experience. Alongside him is Luigi Dindo, who just retired from Michelotto, so is just the right choice. They have the technical capacity to read the data and follow it, so we are improving the process, and that was a necessary step to take.

'Of the 10 manufacturers, eight have pro' cars and seven are supporting financially, so it has become customer racing at a high level of manufacturer involvement. It needed to be better structured, and I think we have done the right thing.'

This is a cost-effective way of balancing performance. For the manufacturers, it is cheaper to have an argument than develop a car, and for the teams it is cheaper than introducing more technology.

National struggle

Even with these efforts to control cost, and despite the success of the international series, national GT racing is struggling for grid numbers. The British GT, French GT and others have seen a noticeable decline, while the GT World Challenge Europe races are incredibly popular in both sprint and endurance form.

'We are developing globally, but it is a fact that if you see today, and it is a paradox, that for a certain budget and wealth, people are protected from the ups and downs of this world,' says Ratel. 'Looking at GT4, where you are talking a couple of hundred thousand to do a season, it is business owners and smaller budget levels. That is where you see a hit.'

So, is there an increased draw for international racing that allows teams and their customer drivers to compete? If so, what is it? 'It is a combination of fact,' says Ratel. 'The first is that Europe may have failed in many aspects, but it has succeeded in something – people feel more European than they were. They have achieved this clearly from the position 15-20 years ago when we had a full generation of gentlemen drivers who didn't speak English, that were not comfortable in international championships and who wanted to stay home. The new generation all speak English, and like driving in an international series.

'The second is the brand effect, which means everyone wants to race on the big circuits. The Grade 1 stamp is attractive. Racing at tracks like Snetterton, Lausitzring or Lédenon are a hard sell for teams and drivers. GT Open, us, European Le Mans Series, they are all international series that race on the big circuits and are doing well, while the national championships struggle more.

'The moment you start putting the calendar on the old, traditional, local circuits, people drag their feet a little bit. England was protected because of the extra cost of going to the continent. The crossing is expensive, the carnet is a pain in the neck, accentuated by Brexit, so it is more complicated now than it used to be to race on the continent.

'However, I read an article in *Time* magazine that said 11,500 millionaires, and others, have left London in the last year. Those people are our clients, and when people leave a country, you have less players. One of our clients moved to Monaco, another to Dubai, another somewhere else. They are not in the country any more, and this is a reason why we are seeing an impact on British GT. That series was always the most stable, the one that was not even a question.'

On the topic of trade tariffs, teams are facing a potential increase in costs for spare parts, but it's the uncertainty that is causing the worry. No one knows what the tariffs will do to one series or another, as parts for the cars that race in them come from all over the world. In the GT World Challenge, tyre supplier, Pirelli, has a fixed price for the season for its product, but that is unusual. Teams will already have fixed their 2025 contracts, and budgets, with their drivers and sponsors for the year and no one wants to have to re-negotiate all of that. 'It is a time of high uncertainty for everyone,' confirms Ratel, 'and that is not good. Racecars have parts from all over the world, even good old American racecars, and right now no one knows if the tariffs will be 10, 20 or 25 per cent.'

So, while GT3 continues its incredible upward trajectory on the international stage, Ratel remains justifiably cautious, and will protect his competitors as much as he can. On the national stage, there is clearly more work to do, but the Frenchman is not out of ideas just yet to fix that.

'It has become customer racing at a high level of manufacturer involvement. It needed to be better structured, and I think we have done the right thing'

SRO / JEP

At time of writing, no one knows what the effect of proposed tariffs will have on international motor racing, but the uncertainty discussion around them brings is not welcome

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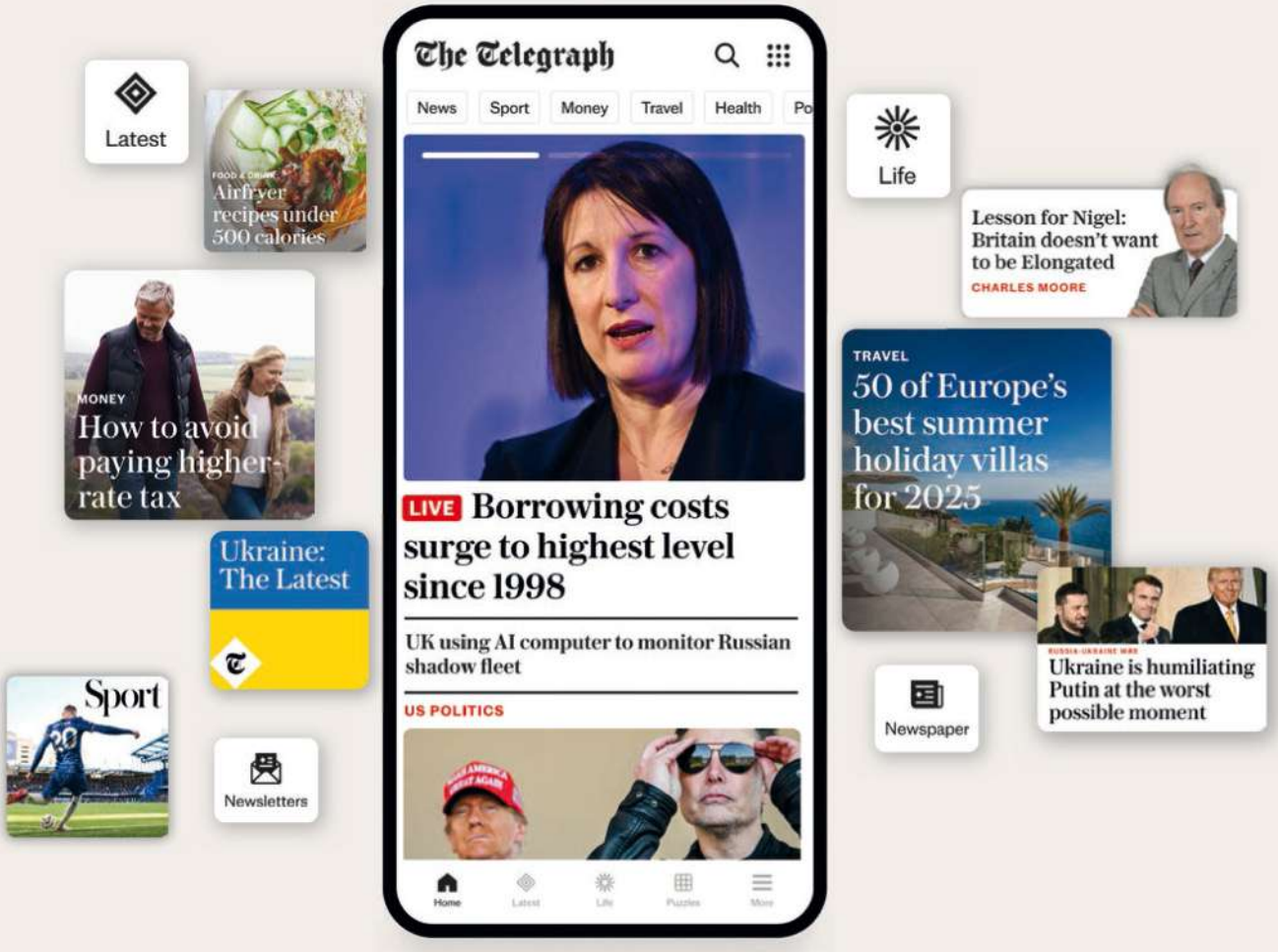

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IN BRIEF

McLaren has confirmed it will enter the FIA World Endurance Championship in 2027. There were few details given in the recent announcement, but *Racecar* believes the deal is done with Dallara to provide the LMDh chassis, while the engine detail has yet to be finalised. McLaren will join Ford as a debutant in 2027.

Craft Bamboo Racing will partner with **Radical Motorsport** to launch Radical Japan. Radical is the UK's most prolific racecar manufacturer, second only to Porsche in overall volume. The agreement will see the Radical SR3 XXR and other models made available to the Japanese market.

The **SRO Motorsports Group** has joined the **Thailand Super Series**. TSS will use the SRO's performance balancing system for its GT3 and GT4 cars, as well as Pirelli tyres, and stands to benefit from the organisation's international reach. The partnership with TSS further strengthens SRO's presence on the Asian continent, which already encompasses GT World Challenge Asia, Japan Cup and the new SRO GT Cup in China. The SRO also works alongside the FIA to organise the FIA GT World Cup in Macau, and with the ACO in overseeing the Asian Le Mans Series.

McLaren Racing, **Deloitte UK** and the **FIA** have launched an *F1 Constructors' Circularity Handbook*, designed to improve sustainable practices in the development and manufacture of a Formula 1 car. It includes a guide to apply circularity to different input materials and waste streams, for example. The goal is for the Handbook to be rolled out across wider racing.

An LMDh prototype unofficially undercut the Goodwood official lap record during the circuit's annual Members Meeting, held in mid-April 2025. *Racecar Engineering* and the team running the car both informally timed the **Jota Cadillac V-Series.R** at 1m5s during a set of high-speed demonstration laps by Will Stevens, which, were it to stand, would be four seconds quicker than the existing official lap record.

Ligier consumes Mygale

French racecar manufacturer, Ligier Automotive, has expanded its portfolio to include the historic Mygale name under a new banner, Ligier Advanced Technologies. The company purchased a minority stake in Mygale, which has been going for 35 years, in 2013 and then expanded that to a majority stakeholding at the end of 2024.

Based at Mygale's former headquarters at Magny-Cours, France, Ligier Advanced Technologies will take on its predecessor's design and manufacture of single seaters and other special project cars. It will also support Ligier Automotive's sportscar programme, which is based in a separate facility on the same site.

As part of the transition to Ligier Advanced Technologies, all Mygale cars will gradually be re-branded to Ligier. The Mygale M21-F4 chassis that races in the French, Chinese and Indian FIA Formula 4 championships is now called the Ligier JS F422.

Jacques Nicolet, president of Ligier Automotive

A slightly different car of the same name remains active in the United States series and will continue to be produced by regional subsidiary, Ligier Automotive North America, which bought Crawford Race Cars in 2016.

Ligier Advanced Technologies is currently working on a new FIA Formula Regional chassis for 2026.

'This name change is a natural and strategic evolution,' says Bertrand Decoster, general manager of Ligier Advanced Technologies. 'It reflects our drive for excellence by leveraging the strength of the Ligier brand while continuing to do what we do best: design and manufacture high-level vehicles and components. This is a new chapter, but our DNA remains the same.'

Ligier Automotive president, Jacques Nicolet, adds: 'Bringing Mygale under the Ligier brand is part of our ambition to offer a clearer, more consistent, and more ambitious range of products and services. Ligier Advanced Technologies reflects our ability to innovate, manufacture and support constructors, federations, series organisers and racing teams with top-tier solutions across all areas of motorsport.'

Mygale chassis currently race in Formula 4 around the world. Shown here is the US F4 championship round at Circuit of The Americas, Texas

TCR World Tour goes green on ETS fuel

The FIA TCR World Tour series will be powered by sustainable fuels from Haltermann Carless for the 2025 season. The fuel was first used in the touring car race of the FIA World Motorsport Games that was held in Valencia in 2024.

The fuel is made from 50 per cent certified advanced sustainable materials, derived from biomass waste, and offers a 30 per cent drop in greenhouse gas emissions compared to fossil fuels. It is certified by the WSC and available to any other TCR series around the world.

WSC president, Marcello Lotti, says there is more to come for his TCR platform: 'This is only the first step. Together with Haltermann Carless, we are aiming to further improve our sustainability in the near future.'

Yann Labia, ETS Racing Fuels global manager, adds: 'This fuel has been developed as a drop-in solution for TCR cars, with OEMs successfully testing it and confirming that no issues arose when using it. The 2025 season will provide an opportunity to demonstrate the fuel's performance across various geographic regions and climates, starting from Mexico, showcasing that sustainable fuel technologies are readily available to power internal combustion engines, while helping to reduce greenhouse gas emissions.'

First fire of Genesis LMDh engine

Korean luxury car manufacturer, Genesis, has confirmed it has completed a successful first firing of its engine, which will compete in the FIA World Endurance Championship in 2026. The event took place late in February 2025 and was critical to the success of the programme as the cooling requirements have yet to be set within the ORECA chassis in which the engine will sit.

Any delay in the engine development would impact the design and subsequent testing programme for the car, and that then threatened to impact Ford's preparation, with the Blue Oval also believed to have settled on an ORECA chassis for its entry in 2027.

The V8 engine, essentially two of Hyundai's four-cylinder WRC engines mated, has been produced in-house by the Hyundai team that has built the WRC engines since 2017. It follows a path previously trodden by the American Glickenhaus team, which used two Pipo Moteurs rally engines joined together for its LMH contender, the 007.

'We have a very strong team in Hyundai Motorsport,' says Julien Moncet, Hyundai Motorsport's head of powertrain. 'We have everyone working on the powertrain all together, so the communication is very good between the departments, feeding information back between simulations. This can speed up the development process and it means we can immediately adapt as soon as we see something, without losing time.'

Hyundai's GMR-001 Hypercar project passed a major development milestone in February with the successful fire-up of its new, rally-derived V8 power unit

The new powerplant retains the basic architecture of the inline fours from which it is derived, the two units sharing roughly 60 per cent of their parts. The four-cylinder engine, in turn, is based on the FIA's Global Race Engine regulations, which Genesis hopes will provide a strong and thoroughly tested foundation for the GMR-001 Hypercar's engine.

'The inline-four engine is a very sophisticated, very efficient engine,' notes Hyundai Motorsport technical director, François-Xavier Demaison. 'It's a proper race engine, so it's a very good base for developing an engine for WEC. Rallying is a sort of endurance race so, for an engine to do the 24 Hours of Le Mans, it's a good place to start from.

'With the timeframe we had available, we immediately knew we did not have enough time to design a new engine from scratch. For the main part of an engine, you need a long time to design, validate and, of course, to produce. Every part needs to be tested over many kilometres, and the inline-four engine from our World Rally Championship car has already been well proven. It became the logical step to carry over as many parts as possible from the four-cylinder engine.'

Design work on the V8 version began in June 2024, and was completed just four months later. The assembly of the first engine was undertaken early this year in time for the scheduled fire-up.

'The first part of the project was to extrapolate what we knew from the WRC engine into endurance racing,' explains Moncet, 'Then we focused on making improvements to aspects like efficiency and reliability, design and simulation, working hand-in-hand to define the engine.

'The assembly of the first engine always takes a bit more time, as we pay extra attention to the details because we don't know the engine. We had to learn and build the documentation together. It took about three or weeks, but we completed the first fire-up exactly as scheduled.

Hyundai Motorsport engineers, working with their Genesis Magma Racing colleagues, will now focus on completing a series of bench tests with the engine, before connecting it to the car's gearbox and then to the hybrid unit common to all LMDh-specification cars.

In line with the news of the new engine development, Genesis Magma Racing took the wraps off its full-scale GMR-001 Hypercar, which it describes as ushering in a new era of athletic elegance

IN BRIEF

Lola Cars and **Yamaha** have agreed to continue their technical partnership for the Gen4 era of the FIA Formula E World Championship. The two organisations are in their first term of collaboration but will also develop a powertrain for the 2026-'27 season, when power outputs are set to rise.

Malcolm Wilson has been nominated by FIA president, Mohammed Ben Sulayem, as his preferred candidate for deputy president for sport. If confirmed by the FIA World Motor Sport Council and its members, Wilson will replace Robert Reid, who left the organisation in April.

Wilson is the founder of M-Sport, which runs Ford Pumas in the FIA World Rally Championship, and is widely believed to want to rebuild the series.

The FIA has approved **GM Performance Power Units** as an F1 power unit manufacturer. The recently-formed company, soon to be based at a new facility in North Carolina, will build PUs for the Cadillac team in time for the 2029 grand prix season. This is one year later than GM initially proposed when it lodged its request to become a PU manufacturer in late 2023.

FIA meets to set new direction for F1 PUs

The FIA has held its first meeting to discuss the financial governance of the new Formula 1 powertrain regulations that are coming in 2026, and future regulations that are due to be implemented in 2031. Hosted in Bahrain, the meeting gave consideration to adopting normally aspirated engines that use sustainable fuel, in a bid to reduce the overall price of hybrid engines.

The meeting, chaired by FIA president Mohammed Ben Sulayem, the CEO of FOM, Stefano Domenicali, and FIA single seater director, Nikolas Tombazis, was attended by representatives in person and via video conference from Audi, Ferrari, Ford, General Motors, Honda, Mercedes and Red Bull Powertrains.

This is the first in a series of meetings designed to set a stable path through what can only be described as turbulent times, which will see grand prix racing adopt a higher percentage of electrical power under its 2026 regulations, while the ICE component will use sustainable fuel.

A release from the FIA stated that the decisions taken in this preliminary meeting included confirmation that 'a level of electrification' will be considered in the future, while the use of sustainable fuel is imperative.

Also discussed were the financial regulations relating to power units as part of broader cost reductions.

Whichever engine roadmap is decided upon, the FIA is supportive of the teams and PU manufacturers in ensuring cost containment in R&D expenditure, taking account of environmental considerations and acting in the best interests of the sport and the fans.

The last time a non-hybrid Formula 1 car raced in grand prix competition was in Brazil 2013, when Sebastian Vettel won his fourth and final World Drivers' Championship title for Red Bull

SEEN: NEXT GEN PORSCHE 911 GT3 R

Porsche blooded its next generation 911 GT3 R at the 12 Hours of Spa in April, ahead of a full launch this summer. Modifications have been made to the existing model including revised aerodynamic elements designed to reduce pitch sensitivity by improving front-end behaviour under braking and acceleration. *Racecar* understands important software updates have also been implemented, and the car's steering system has been further refined. The car will compete in GT3 racing around the world in 2026.

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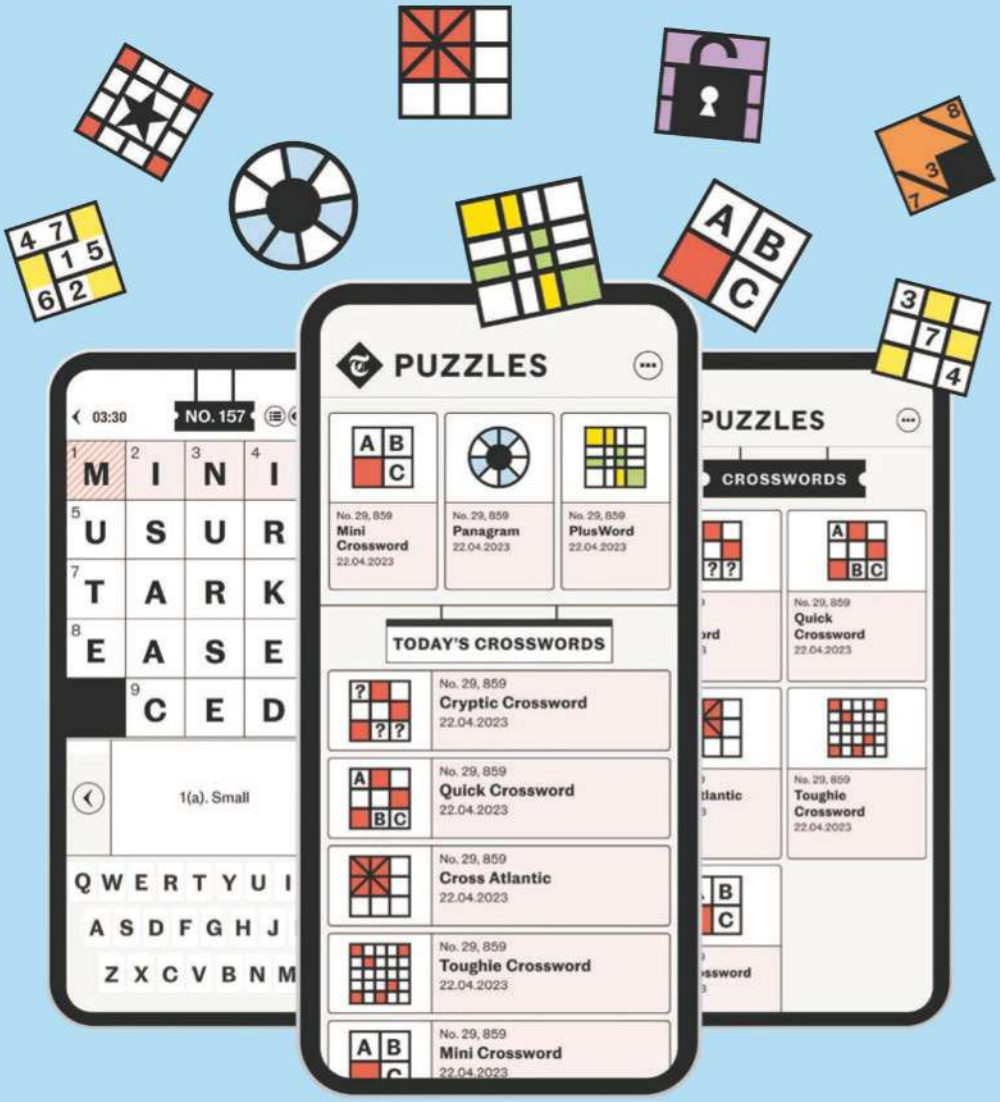

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Trade (dis-)agreement

The imposition of tariffs is a hot topic, but how will it affect motor racing?

Racing has become an international business and every racecar on track these days is made up of parts assembled from around the world. It's not uncommon to see radiators for grand prix cars from Australia, gearboxes and electronics from the UK, chassis from Italy, suspension products from Canada and tyres from an Italian company with a factory in Turkey. Consequently, the concept of international trade tariffs has rather thrown a spanner in the works. The threat is not immediate, as no one really knows what is going to happen, but the uncertainty is certainly causing concern.

Accelerated delivery

For some, the threat of increased costs, either to the manufacturer or the team, has accelerated delivery of stock to beat the deadline. Anyone looking to supply to America, and which doesn't build the components in the US, shipped as much stock as possible, as early as possible. Others are hoping to use up stock already in the US and hope the threat of tariffs goes away. One global player is even looking to change its production cycle to include factories around the world, but that's an exceptional stance.

Teams, and drivers, that compete in international series look likely to face increased costs. Those in the US will be the first to experience it, but costs will rise for series around the world. It remains to be seen what happens with the new LMP2 regulations, for example. These cars are built to a cost cap and sold for a prescribed maximum price, while the leasing of engines and gearboxes is strictly controlled on cost, too. However, teams in the US will run the cars. The likelihood is America will be a major market for the cars, thanks to IMSA's commitment to the category, so what is a European supplying company expected to do?

For a constructor such as Dallara, which supplies chassis to IndyCar, IMSA and NASCAR, tariffs could pose a problem. Increased costs would have to be swallowed by someone, be it Dallara, the teams, the sponsors or the paying drivers. IndyCar gearboxes, meanwhile, come from Xtrac and the hybrid system from Empel, both in the UK. As Stéphane Ratel pointed out in an interview for this magazine, no one knows if racing will be exempt from the tariffs, or if the tariffs will be 10, 20 or 25 per cent.

Then what happens if Italy is granted a zero per cent tariff rate, but not the rest of Europe (possible, at time of writing, but it's a fast moving world).

Could production be shifted to the US to avoid the tariffs? Not in a hurry. Supply chains, expertise in build, even down to metrology and quality control, are all set up in one location, established long before the financial world went into meltdown. To move it would be senseless as these companies remain global players, and besides, other countries, or regions, may introduce reciprocal tariffs. To duplicate manufacturing processes would make even less sense, as no one has the money to do that.

Many plan to simply ride out the storm, hoping tariffs will either not be introduced at all, or will be temporary, whether under the current US administration or the next. It's unlikely to lead to a long-term shift in racing supply chains but, if costs rise in line with the extra tax placed on imported goods, it will almost certainly have a short-term effect on grid numbers, and series organisers might start looking at their suppliers.

It's unlikely to lead to a long-term shift in racing supply chains but… it will almost certainly have a short-term effect on grid numbers

It wasn't that long ago that a trip to Macau introduced the international media to different chassis suppliers, engine providers, sponsors and drivers on the Formula 3 grid. The local GT series was a joy to behold, offering variety and novelty.

A recent trip to the US saw the latest chassis designs from American companies, and experimental technologies. Japan traditionally follows its own path when it comes to design, to the point the racing scene there was both outlandish and exciting. It still retains a mystical aura, but now has the Class 1 chassis, which does not look like changing in Super GT, and Dallara chassis in Super Formula.

Primary driver

Safety, cost and supply chains drive the market, and there is a reason the companies selected are in such demand. The ability to produce safe, reliable components, and support teams running them, wherever they are, is also critical to success. The chance to open it up a bit to other players *could* be an exciting prospect but, for now, we have to sit back and wait to see what actually happens, assuming it doesn't then change again…

ANDREW COTTON Editor

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